Enhanced Snake Plain Aquifer Model

Version 2.1

Uncertainty Analysis

Idaho Department of Water Resources
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Abstract

The Enhanced Snake Plain Aquifer Model Version 2.0 (ESPAM2.0) was, developed by the Idaho Department of Water Resources (IDWR), with oversight from the Eastern Snake Hydrologic Modeling Committee (ESHMC). After completion of ESPAM2.0 mistakes were identified in the water budget in the Mud Lake area. The mistakes were fixed and the model recalibrated using the repaired water budget resulting in ESPAM2.1.

During model development the ESHMC considered completing an uncertainty analysis the third highest priority in producing ESPAM2.0. The process of deciding how to evaluate predictive uncertainty was more complicated than deciding that evaluating predictive uncertainty was necessary. The ESHMC eventually chose a limited analysis that involved imposing a stress at eight locations on the eastern Snake Plain, and determining the impact of parameter uncertainty on key predictions using a procedure proposed by Doherty (2010) and Doherty and others (2010). This technique locates the maximum and minimum values for the selected prediction by adjusting model parameters, while still keeping the model calibrated. The technique identifies how well the calibration dataset constrains the selected predictions but not the probability of any one prediction being true.

The results of this analysis indicate that about 82% (14/17) of the analyses had low predictive uncertainty, about 18% (3/17) of the uncertainty analyses identified predictions with uncertainty greater than 0.10 (difference between fraction of maximized impact and minimized impact realized at the target reach). Interestingly all the predictions with high uncertainty evaluated the impact of centroids northeast of American Falls Reservoir on the near-Blackfoot-to-Minidoka reach of the Snake River; however, not all centroids northeast of American Falls Reservoir registered high uncertainty for their impact on the near-Blackfoot-to-Minidoka reach. The hydrographs of Snake River reach-gains contain significant noise (erroneous data), and the IDWR suspects this noise contributes to the observed uncertainty since the model cannot match the noise. The IDWR experimented with including both filtered and unfiltered reach-gains and found that including filtered reach-gains in the calibration dataset reduced the predictive uncertainty range by about 37%. The IDWR proposes using both filtered and unfiltered Snake River gains during model calibration in future versions of the ESPA Model.

Introduction

The eastern Snake Plain Aquifer (ESPA) extends from Ashton, Idaho in the northeast to King Hill, Idaho in the southwest (Figure 1). The Enhanced Snake Plain Aquifer Model Version 2.0 (ESPAM2.0) was developed by the Idaho Department of Water Resources (IDWR) with oversight from the Eastern Snake Hydrologic Modeling Committee (ESHMC) to incorporate new data and model enhancements to improve the previous model (ESPAM1.1). After calibration of ESPAM2.0, mistakes in the water budget in the Mud Lake area were discovered, repaired and the model recalibrated. The resulting model is referred to as ESPAM2.1. Details of the model are provided in the Final Report (TBD).

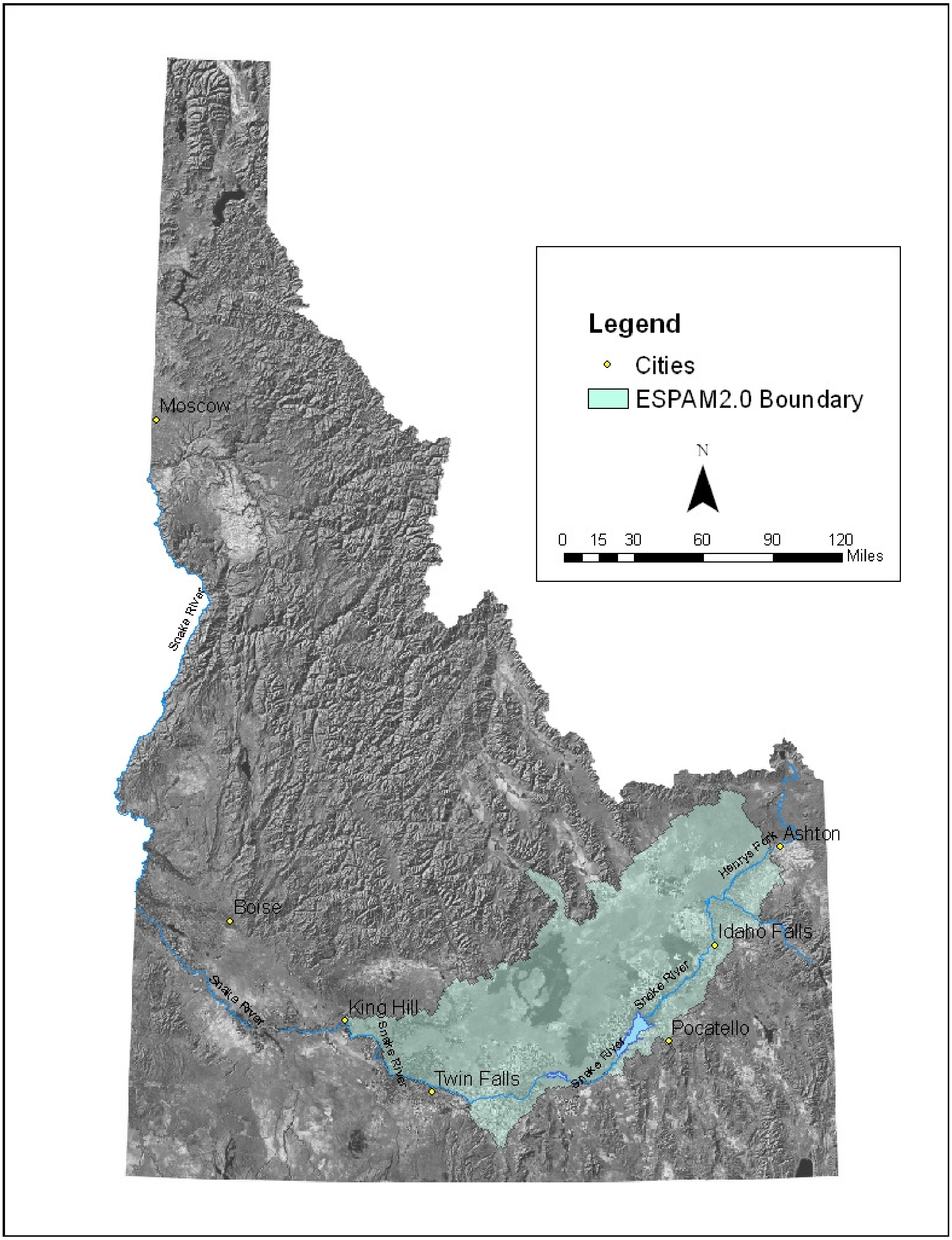

Figure 1. Location of eastern Snake Plain Aquifer.

An understanding of a model's predictive uncertainty is fundamental to the use of the model in support of decision making. Various procedures for evaluating predictive uncertainty have been suggested ranging from a sensitivity analysis to a complex Monte Carlo analysis (Doherty and others, 2010; http://www.idwr.idaho.gov/Browse/WaterInfo/ESPAM/ESHMC%20Updated%20White%20Paper/). In a traditional sensitivity analysis, selected model inputs are varied, and the associated changes in model outputs are recorded. Monte Carlo analyses require many model realizations, each of which is recalibrated and used to make key predictions. The set of predictions are then used to generate probability distributions. Doherty and others (2010) present a number of techniques that may be used to complete predictive uncertainty analyses.

In 2007, the ESHMC identified goals for development and calibration of ESPAM2.0, and the committee members independently ranked the components that they considered most important. Completing an uncertainty analysis was ranked as the third highest priority for ESPAM2.0. In the November 2009 ESHMC meeting, the committee chose to evaluate predictive uncertainty using PEST (Doherty, 2010) following the procedure outlined by Doherty (2003). In the February 2010 ESHMC meeting this decision was modified to use the nonlinear analysis proposed by Doherty (2010). During the March 2011 ESHMC meeting, the committee unanimously agreed to proceed with a predictive uncertainty analysis immediately after calibration of ESPAM2.0. In the June 2011 ESHMC meeting, the committee chose to reduce the scope of the analysis because an exhaustive uncertainty analysis for a complex model like the ESPAM2.0 would be time-prohibitive. The committee chose a limited predictive uncertainty analysis that involved imposing a stress at a centroid within each of eight areas on the ESPA, and determining uncertainty for the impact of the stress on two springs and two river reaches. The eight areas chosen were: Water District 100, 110, 120, 130, 140, 33, 34, and the Rexburg Bench, hereafter referred to as Water District 99, or WD099. The chosen springs were Blue Lake and Clear Lakes, and the chosen river reaches were near-Blackfoot-to-Minidoka and Ashton-to-Rexburg (Figure 2).

The uncertainty analysis commenced in August 2011 and continued until August 2012. Calibration run E120116A008, referred to as ESPAM2.0, was completed in March 2012, so several of the uncertainty analyses were conducted using a preliminary calibration run. The ESHMC concluded that one of the preliminary runs should be rerun with E120116A008 to assess the changes due to different calibration runs. While the uncertainty analysis was in progress, the ESHMC decided to further limit the scope and only analyze uncertainty at one spring, Clear Lakes, and one river reach, near-Blackfoot-to-Minidoka.

The first eight characters in the 11 character calibration run name identifies the water budget used, for example E120116A. The last three characters indicate the calibration run conducted using that particular water budget, for example 008. Thus E110712A002 is the second calibration run conducted with water budget E110712A and E120116A008 is the eighth calibration run conducted with water budget E120116A.

After calibration of ESPAM2.0, mistakes in the water budget in the Mud Lake area were discovered, repaired and the model recalibrated. The corrected water budget is E121025A and the resulting model is E121025A001, commonly referred to as ESPAM2.1.

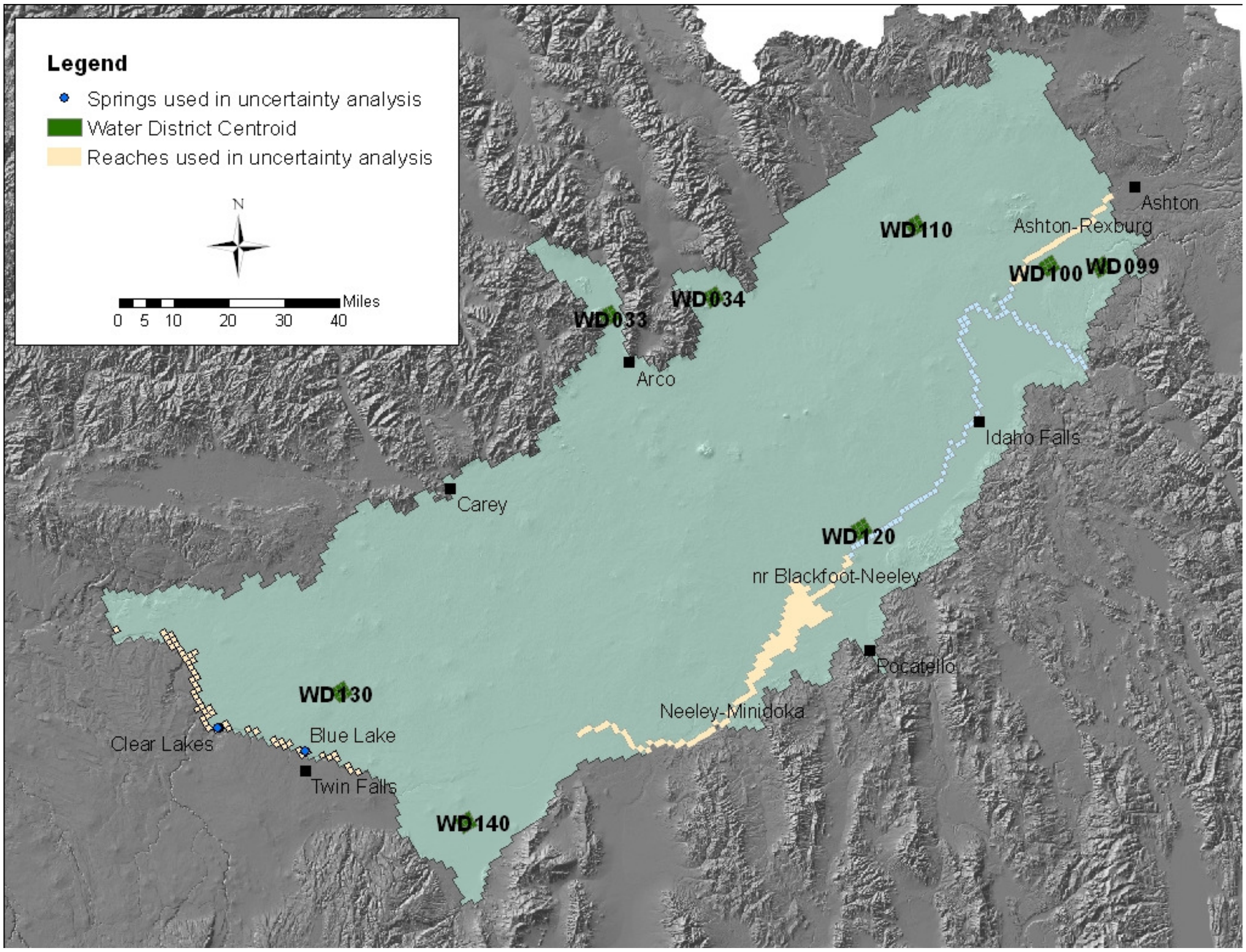

Figure 2. Water District centroids and springs and river reaches.

Methodology

Models are calibrated by adjusting parameters to reduce the discrepancy between model outputs and field observations. The discrepancies are encapsulated in an “objective function”; defined as the weighted sum of squared differences between field observations and model outputs. Generally, the topology of the objective function in parameter space is shaped like a long, narrow valley of nearly equal objective function values, with the objective function minimum placed somewhere in the bottom of the valley. The parameter distribution that describes this long narrow valley calibrates the model. Thus the model calibration is not unique. Normally, as in the case of ESPAM2.1, a single set of parameters is chosen as “The Model” (i.e. E121025A001) and used to make predictions. Given this long narrow valley in the objective function, an obvious question is, “what would have been the prediction if another set of parameters lying along the valley bottom were chosen?” An effective way to investigate the variability of a model prediction while maintaining goodness of fit between model outputs and field observations is with a constrained maximization/minimization technique similar to the procedure proposed by Doherty (2010) and Doherty and others (2010). This technique keeps the model calibrated while identifying the critical values along the parameter-space valley where the selected prediction is either maximized or minimized.

The following is the procedure used to identify how correlations in adjustable parameters can impact the selected predictions.

1) Identify the centroid of the irrigated lands within the water district or selected areas. The centroids are not intended to represent the water districts in this analysis, they are intended to be widely distributed on the ESPA, and constrained to areas where irrigation is taking place.
2) Prepare the model files necessary to run the prediction, including a stress file constructed using the 3x3 cell centriod identified in step one (1).
3) Make a copy of the PEST control file. The PEST control file contains all of the adjustable parameters and their bounds, and all the field observations. Since the entire PEST control file is copied, every parameter adjustable in a calibration run will also be adjustable in the predictive uncertainty analysis, and every field observation used as a calibration target will also be used as a target in the predictive uncertainty analysis. The following adjustments (items 4 – 12) were made to the PEST control file.
4) Replace the word ‘regularization’ with the word ‘prediction’ on the third line.
5) Increase the number of observations by one (1) because the prediction will be a new observation.
6) Increase the number of observation groups by one (1) because there will now be an observation group ‘predict’.
7) Increase the number of instruction files by one (1) because PEST will now be required to monitor the prediction.
8) Add ‘predict’ to the list of observation groups.
9) Add an observation representing the prediction to the observation section. Any weight and target observation value can be provided because PEST ignores the weight and target observation value for any observation in the ‘predict’ group when it is run in predictive analysis mode.
10) Change the model command line to reflect the name of the batch file used to run the model and the prediction.
11) Add the name of the new instruction file and the output file it will read to the list of files used to read model output.
12) Add a ‘predictive analysis’ section to the control file. This will include NPREDMAXMIN, PD0, PD1, and PD2. NPREDMAXMIN instructs PEST to either maximize (+1) or minimize (-1) the prediction of interest. PD0 is a value of the objective function (phi) which is considered calibrated. Because the shape of the PD0 envelope can be complex, it is extremely hard for PEST to identify a parameter set that lies exactly on the boundary. Therefore, PD0 must be greater than phi for the calibrated model, but only slightly greater. The value supplied for PD1 (which must be slightly greater than PD0) is a value PEST will consider “close enough”. If the sum-of-the-squared residuals is above PD2, PEST tries to minimize the objective function until the objective function is below PD2, at which point PEST begins searching for either the maximum or minimum value for the prediction at PD0.

Thus, during a predictive uncertainty analysis run, PEST will: A) run MKMOD, B) run MODFLOW, C) compare model output with field observations in the same manner as in a calibration run, D) compare the sum-of-the-squared residuals (phi) from this run with PD0, E) make a model run in superposition mode containing only the 3x3 stress file constructed during steps 1 and 2, F) collect the predicted impact at the target spring or river reach, and G) compare this prediction with the previous maximum (or minimum) prediction and save the value, if it is a new maximum (or minimum) and if phi for this run is less than PD1.

Doherty (2010) recommends that phi from the calibrated model <PD0 < PD1 < PD2 and that PD0 should only be slightly larger than phi for the calibrated model (1or 2% larger). Doherty (2010) further states that PD1 should only be slightly larger than PD0 (1 or 2% larger), and PD2 should be generally 1.5 to 2 times PD0. Table 1 shows the phi, PD0, PD1, and PD2 values used in this scenario with calibration run E120116A008 and E121025A001. In both cases PD0 is 1.5 % larger than phi, PD1 is 1.5 % larger than PD0, and PD2 is 1.5 times larger than PD0. Functionally, assigning PD0 and PD1 values a little larger than the calibrated phi allows PEST enough latitude to explore parameter space and locate correlated parameters that might impact the selected prediction.

Table 1. Phi, PD0, PD1, and PD2 values used for predictive uncertainty analysis with calibration run E120115A008 and E121025A001.

Model	phi	PD0	PD1	PD2
E120116A008	26517	26915	27312	39776
E121025A001	26613	27012	27417	39919

A comprehensive predictive uncertainty analysis would yield a probability distribution of the difference between model output and actual aquifer response for the selected predictions. To accomplish such a goal, the analysis would have to interrogate all sources of uncertainty including conceptual model uncertainty, model parameter uncertainty and measurement uncertainty. The maximization/minimization procedure employed in this analysis provides some measure of predictive uncertainty while still being performable within a reasonable time frame. In lieu of a probability distribution, the maximization/minimization analysis provides upper and lower bounds for the probability distribution, with output from “The Model” supplying the most likely outcome. The maximization/minimization approach employed in this analysis addresses sources of uncertainty due to correlated parameters, it does not address conceptual model errors or the impact of measurement error; however, confidence in field observations may be reflected in the assigned measurement weights.

Results

As shown in Table 2, 19 analyses have been completed to evaluate the maximum and minimum impact of stress applied at the eight centroids on Clear Lakes and the near-Blackfoot-to-Minidoka reach of the Snake River as well as one analysis to determine the maximum and minimum impact for the centroid of Water District 130 on the Ashton-to-Rexburg reach. The column in Table 2 titled “Calibrated Impact” represents the fraction of the total impact realized in the target reach at steady state.

Table 2. Constrained maximized/minimized uncertainty analyses conducted with ESPAM2.0 and 2.1. Calibrated Impact represents the fraction of the total impact at the centroid that was realized in the target reach.

Centroid	Reach	Calibrated Impact	Maximized Impact	Minimized Impact	Range	Model Version
WD033	Clear Lakes	0.01	0.01	0.01	0.001	E120116A008
WD033	nr Blackfoot-Minidoka	0.61	0.62	0.61	0.009	E120116A008
WD034	Clear Lakes	0.03	0.03	0.00	0.030	E110712A002
WD034	nr Blackfoot-Minidoka	0.68	0.86	0.32	0.537	E120116A008
WD034	nr Blackfoot-Minidoka	0.49	0.76	0.43	0.331	E121025A001
WD099	Clear Lakes	0.00	0.00	0.00	0.001	E120116A008
WD099	nr Blackfoot-Minidoka	0.16	0.30	0.03	0.267	E120116A008
WD100	Clear Lakes	0.00	0.00	0.00	0.000	E120116A008
WD100	nr Blackfoot-Minidoka	0.20	0.20	0.20	0.000	E120116A008
WD110	Clear Lakes	0.00	0.00	0.00	0.000	E110712A002
WD110	nr Blackfoot-Minidoka	0.26	0.27	0.26	0.006	E120116A008
WD120	Clear Lakes	0.00	0.01	0.00	0.005	E110712A002
WD120	nr Blackfoot-Minidoka	0.67	0.91	0.55	0.363	E120116A008
WD130	Ashton-Rexburg	0.01	0.01	0.01	0.000	E120116A008
WD130	Clear Lakes	0.07	0.07	0.07	0.004	E110712A002
WD130	Clear Lakes	0.08	0.08	0.07	0.012	E121025A001
WD130	nr Blackfoot-Minidoka	0.22	0.22	0.15	0.067	E120116A008
WD140	Clear Lakes	0.05	0.05	0.04	0.002	E120116A008
WD140	nr Blackfoot-Minidoka	0.35	0.35	0.35	0.003	E120116A008

The column in Table 2 titled “Range” represents the difference between the “Maximized Impact” and “Minimized Impact”. Impact differences are used in this table rather than percent change because, from a model development perspective, uncertainty will always exist, thus the more meaningful metric is the fraction of the total impact, not the percent change. For example, the Calibrated Impact for the centroid of WD120 on Clear Lakes is 0.005, the Maximized Impact is 0.009, and the Minimized Impact is 0.004. The Maximized Percent Change is 80% ((0.009-0.005)/0.005) and the Minimized Percent Change is -20% ((0.004-0.005)/0.005). The Predictive Uncertainty range in percentage is 100% (80% - (-20%)). In this example, 100% uncertainty sounds problematic; however, this analysis indicates that the model cannot remain calibrated and increase the impact at Clear Lakes to more than 0.009. Unless something is wrong with the hydrogeologic conceptualization upon which ESPAM2.0 and ESPAM2.1 are based, the impact for the centroid of WD120 upon Clear Lakes will remain small. In this example, 100% uncertainty does not accurately reflect the fact that we are certain that at least 99% of the impact is not realized at Clear Lakes. It is only after the impact differences (range) becomes large that the uncertainty becomes a weakness worth pursuing during model development.

The majority of the analyses presented in Table 2 conducted with ESPAM2.0 and earlier models resulted in relatively tight predictive uncertainty ranges. Three analyses resulted in ranges greater than 0.10: The centroid of WD034 to near-Blackfoot-to-Minidoka, the centroid of WD099 to near-Blackfoot-to-Minidoka and the centroid of WD120 to near-Blackfoot-to-Minidoka (Figure 2). All of these Water District centroids are northeast of American Falls Reservoir, and all of these analyses involve the near-Blackfoot-to-Minidoka reach. The Snake River reach-gain observations contain significant noise (erroneous data) as shown in Figure 3. The noisy data may be allowing PEST some latitude because the model output will never successfully match the noise.

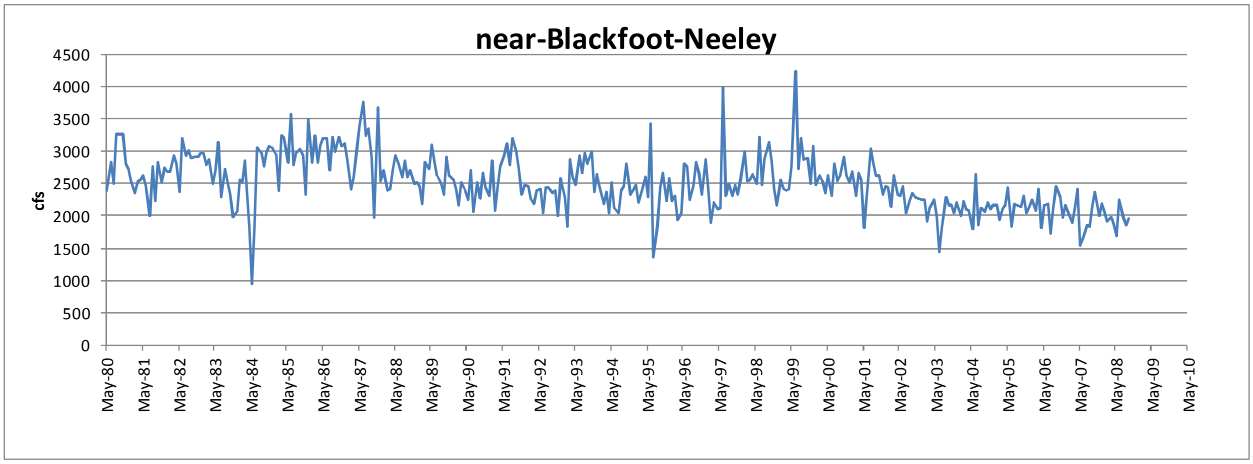

Figure 3. Observed reach-gains between the near Blackfoot and the Neeley gages.

Mistakes were identified in all water budgets used in Table 2 up to E121025A. After correcting these mistakes and producing a new water budget (E121025A) and calibrating ESPAM2.1 (E121025A001). The ESHMC asked IDWR to conducted predictive uncertainty analyses using ESPAM2.1 to compare with previously conducted analyses. The IDWR selected the impact of the centroid for WD034 on near-Blackfoot-to-Minidoka and the impact for the centroid of WD130 on Clear Lakes. These analyses provided comparisons with two different water budgets (E110712A and E120116A), two different target reaches (near-Blackfoot-to-Minidoka and Clear Lakes), an analysis that has a range greater than 0.10 and an analysis that has a range less than 0.10. These analyses are highlighted in gray in Table 2.

In some respects the comparison analyses conducted with ESPAM2.1 are similar:

- Both runs conducted using the WD130 centroid and Clear Lakes indicate that the calibration data constrained the prediction,
- Both runs conducted using the centroid for WD034 and the near-Blackfoot-to-Minidoka reach indicated that the calibration data did not constrain the prediction as tightly as desired.

These similarities show that the elevated uncertainty associated with the near-Blackfoot-to-Minidoka exists after repairing the Mud Lake mistakes.

In some respects the comparison analyses identify differences:

- The ESPAM2.1 impact of the WD130 centroid on Clear Lakes increased from 0.07 to 0.08 and the range increased from 0.004 to 0.012.
- The ESPAM2.1 impact of the WD034 centroid on near-Blackfoot-to-Minidoka decreased from 0.68 to 0.49 and the range decreased from 0.537 to 0.331.

The change in impact with ESPAM2.1 identified in both analyses indicates that the model adjusted physical properties to adapt to changes in where stress is applied in the model. These changes also resulted in changes in predictive uncertainty as evidenced by the change in range. Adjustments such as this are expected in response to changes in the water budget.

Filtered/Unfiltered Reach-Gain Test

The fact that high predictive uncertainty is tied to river reach-gains suggests that the reach-gain calibration targets need to be improved. A Butterworth filter (Butterworth, 1930) is available with PEST and can be applied to remove the noise from the observation data. Even though model output will not contain noise, model output will need to be processed with the same filter prior to comparison with the filtered observations. The noise associated with these reach-gain data suggests that the model is not currently supplied with detailed information concerning seasonal fluctuations through the reach-gain data, and filtering these data will not improve the seasonal information available to the model.

In an attempt to evaluate the impact of data noise on predictive uncertainty, the IDWR conducted an analysis using both filtered and unfiltered reach-gains. This analysis was conducted with ESPAM2.0 (E120116A008) prior to the repair of the Mud Lake mistakes. The steps involved in conducting the analysis include:

1. Interpolate reach-gain data to a constant sampling interval
2. Determine the cutoff frequency
3. Add filtered reach-gains to the calibration targets.
4. Recalibrate the model using both filtered and unfiltered Snake River reach-gain targets.
5. Rerun at least one of the predictive uncertainty analyses.

The Butterworth filter will only work on a time series with a constant sample interval. The reach-gain data is monthly, and months do not have a constant number of days. Therefore, the field observations must be interpolated to a constant interval. The chosen interval was 30.4 days.

The Butterworth filter may be used as a high pass, low pass or band pass filter. The data in Figure 3 contains high frequency noise, so the filter should be designed to remove the high frequency noise and pass the low frequency data through for use in model calibration. An event that occurs once a year has a frequency of 1 per year or 1/365.25 days. The noise in Figure 3 has a frequency of at least 1/365.25 days. This cutoff frequency, or the boundary between the pass band and the stop band, must be identified and provided to the filter.

Figure 4 shows the field observations, interpolated data, and data filtered with cutoff frequencies of 1/365.25 day (1 per 1 year), 1/730.5 day (1 per 2 years) and 1/1826/25 day (1 per 5 years). The cutoff frequency of 1 per 5 years does a better job of removing the noise than the 1 per 1 year or 1 per 2 year cutoffs.

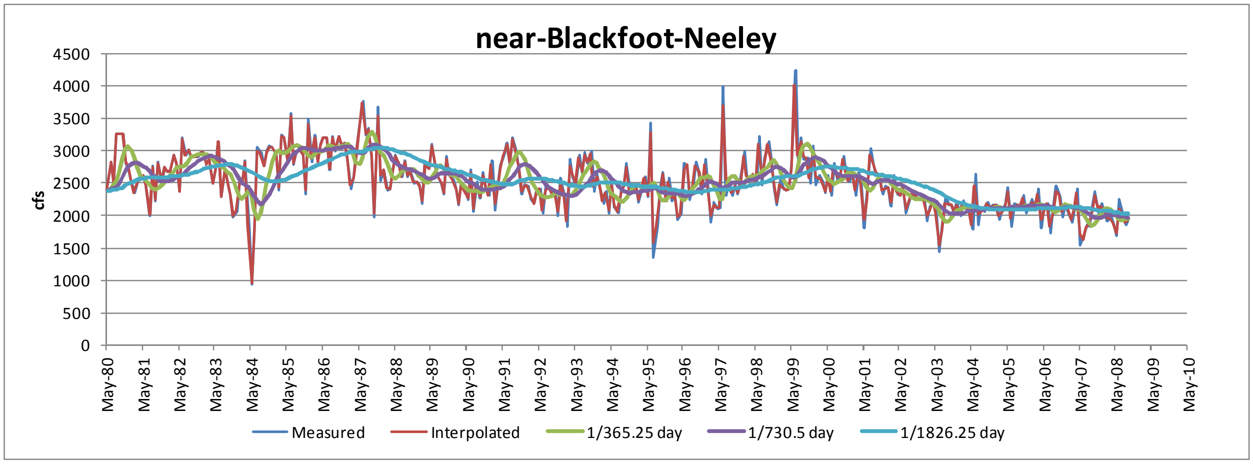

Figure 4. Measured, interpolated, and filtered data for near -Blackfoot-Neeley reach-gains.

The reach-gains filtered using a cutoff frequency of 1/5yr were added to the calibration targets and E120116A008 was recalibrated resulting in model E120116Afilt. Table 3 shows the impact on the predictive uncertainty range. The predictive uncertainty range was reduced by about 37%.

Table 3. Results of the IDWR filtered/unfiltered reach-gain test.

Centroid	Reach	Calibrated Impact	Maximized Impact	Minimized Impact	Range	Model Version
WD034	nr Blackfoot-Minidoka	0.682	0.862	0.324	0.537	E120116A008
WD034	nr Blackfoot-Minidoka	0.542	0.812	0.475	0.338	E120116Afilt

Summary, Conclusions and Recommendations

A comprehensive predictive uncertainty analysis could not be conducted in a reasonable timeframe, so the ESHMC chose to conduct a maximization/minimization uncertainty analysis. In lieu of a probability distribution, the maximization/minimization analysis provides upper and lower bounds for the probability distribution, with output from the ESHMC-chosen calibrated model supplying the most likely outcome.

All of the analyses with a range greater than 0.10 involve the near-Blackfoot-to-Minidoka reach. This indicates that the available data do not adequately constrain the model calibration concerning this prediction. The IDWR recommends that the reach-gain targets should include both filtered and unfiltered reach-gains for future calibrations of ESPAM and that the reach-gain data be analyzed in an attempt to determine the cause of the noise, and remove the noise, if possible.

None of the analyses involving Clear Lakes resulted in significant uncertainty. Perhaps this is because the total impact at Clear Lakes is necessarily small, so the net change cannot be large, or perhaps this is because there is less noise in the spring discharge observations, and the available data adequately constrain the model calibration.

None of the analyses involving centroids within Water District 130 or Water District 140 resulted in significant uncertainty. A possible explanation for this is that most of the impact is dispersed amongst the springs and cannot be shifted elsewhere, if true, the available data are adequately constraining the model calibration.

The impact from centroids within Water District 100 and Water District 110 showed very little uncertainty. Perhaps this is because the model will not calibrate unless a significant portion of the impact from these districts is absorbed by the Ashton-to-Rexburg reach, if so, the available data adequately constrain the model calibration.

Appendix Descriptions

Appendix A contains a map showing the centroid and spring or river reach in which the impact is observed for each of the 19 analyses included in Table 2. Each map is followed by pie charts illustrating how the steady state impact was apportioned between the river reaches and springs: 1) for the calibrated model and for the minimum prediction, and 2) for the calibrated model and for the maximum prediction. Bar charts illustrating fractional change in the adjustable parameters for each prediction are also included. The fractional change was computed by:

$$(prediction - calibration)\ /\ calibration$$

Where: *prediction* is the parameter value used in the maximum/minimum prediction model and *calibration* is the parameter value used in the calibrated model.

Appendix B contains maps pie charts, and bar charts similar to Appendix A for the analysis included in Table 3. Appendix C contains a list of the adjustable parameters. Appendix D contains a color ramp that can be used to relate the colors in the pie charts to individual springs and river reaches. Appendix E contains reviewer comments followed by the IDWR’s response.

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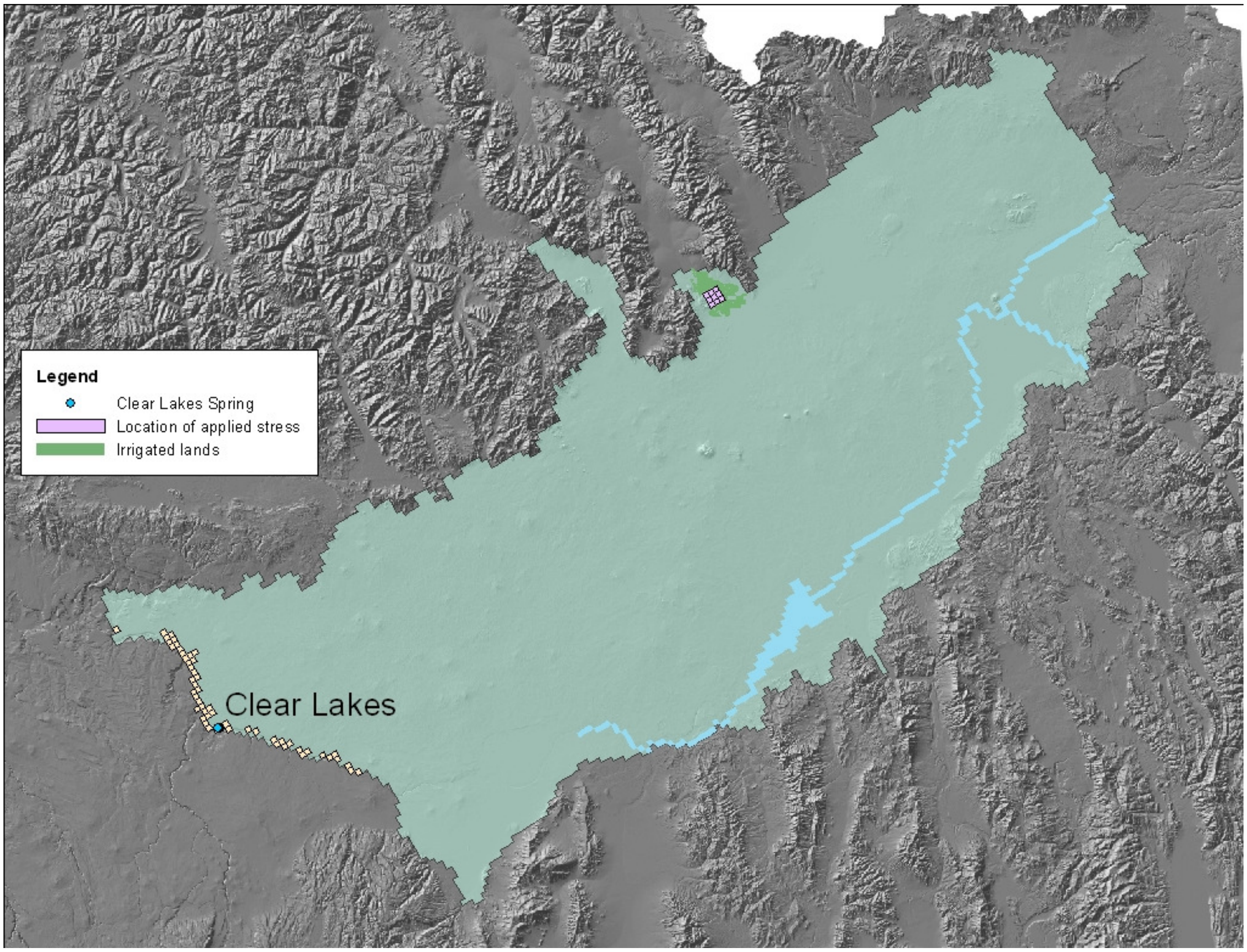
Appendix A; Maps, Pie Diagrams and Bar Charts

Impact of Water District 33 on Clear Lakes using calibration run E120116A008.



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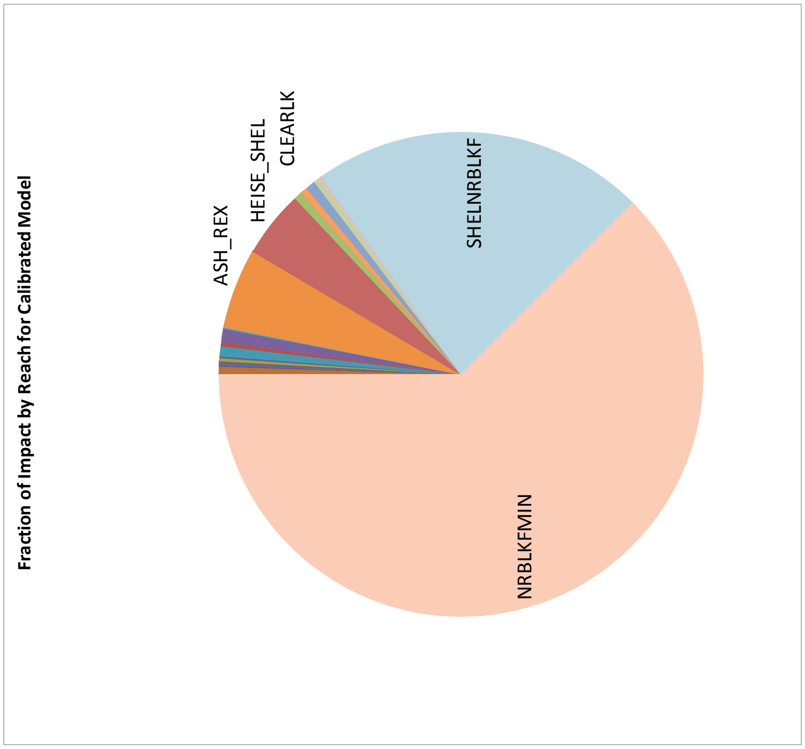

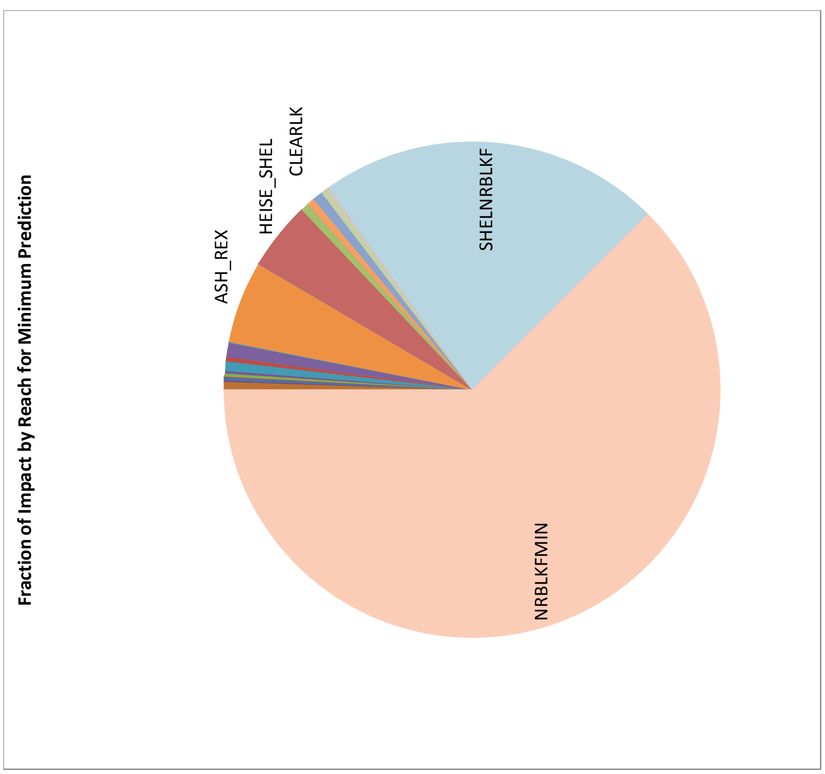

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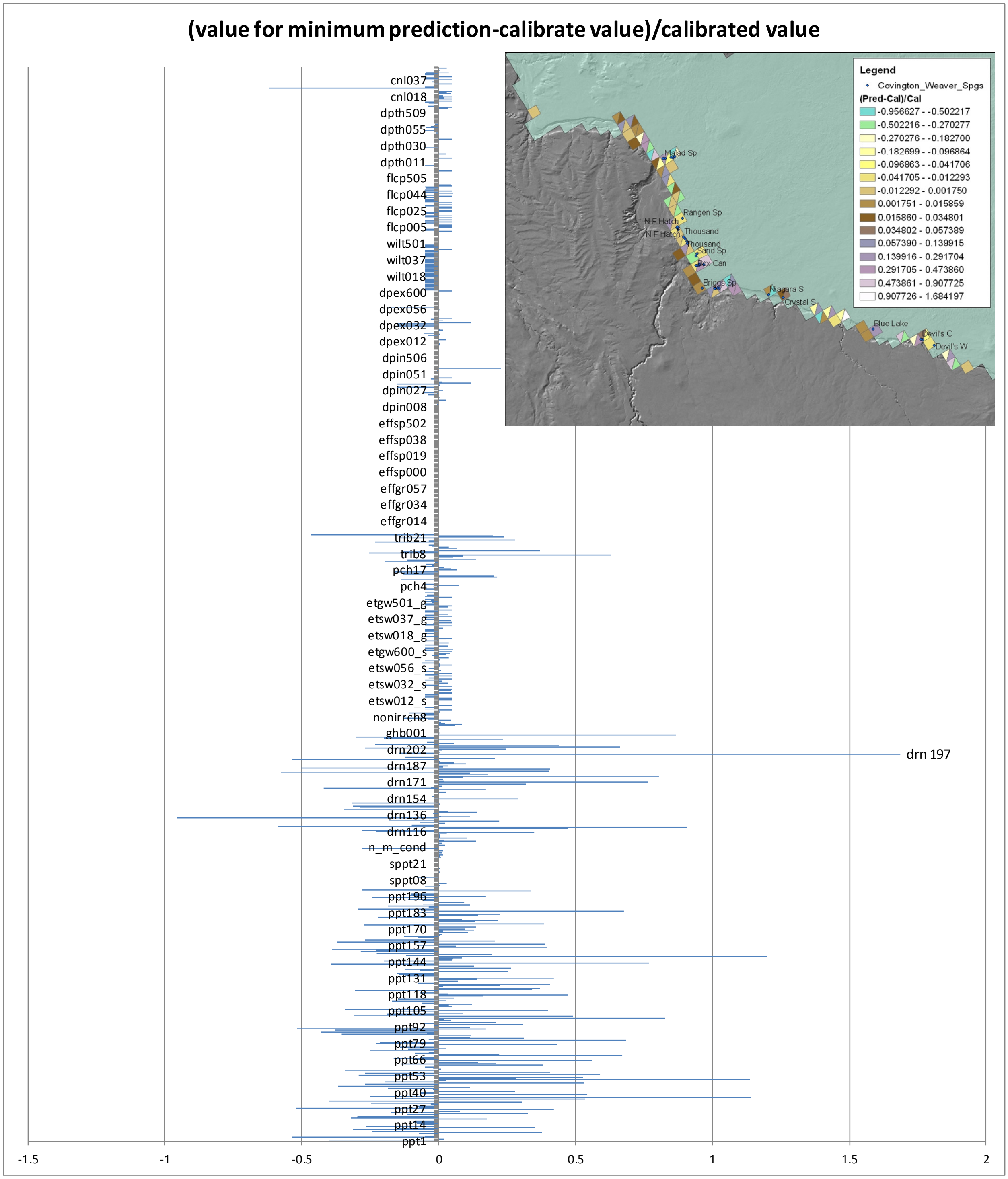

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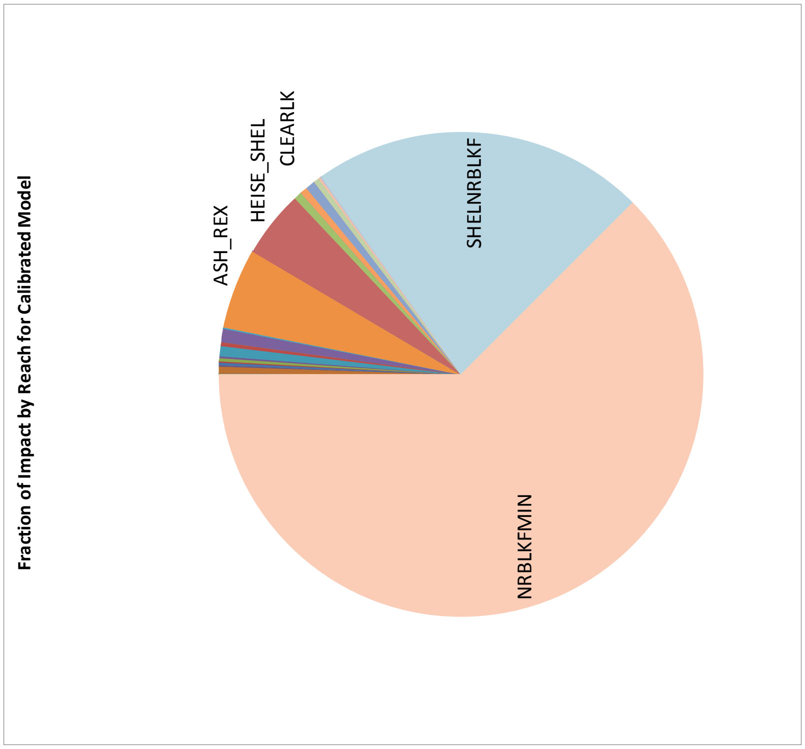

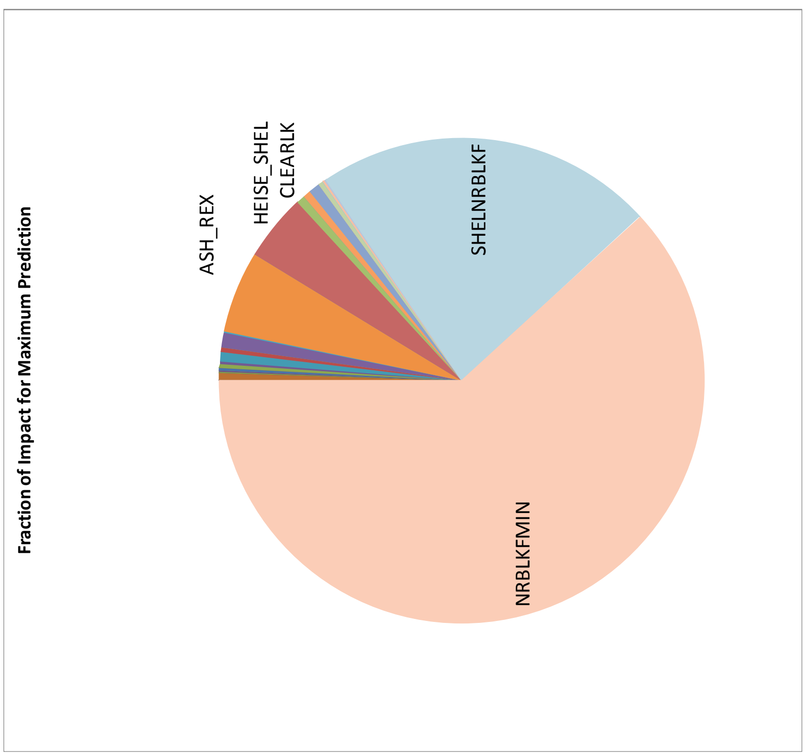

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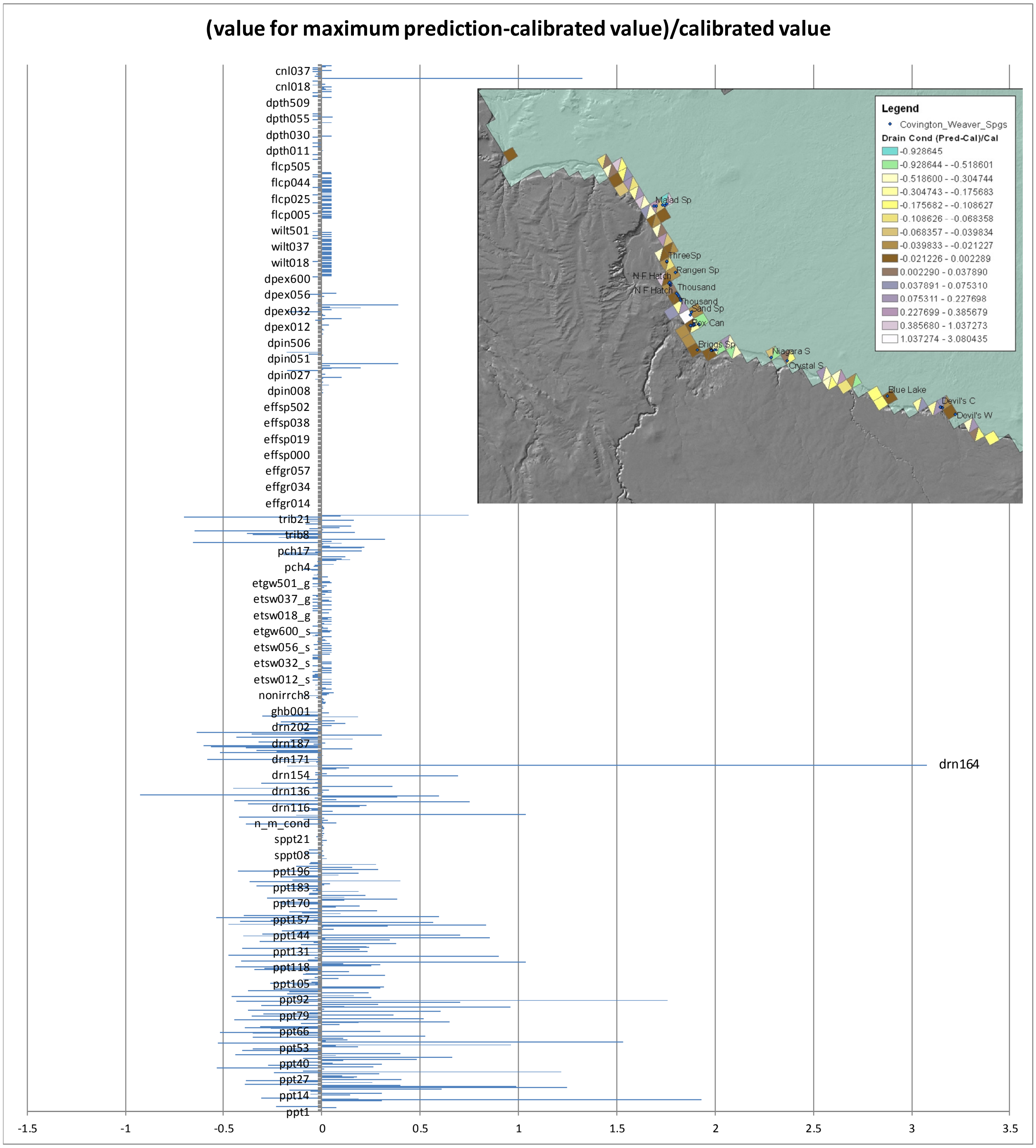
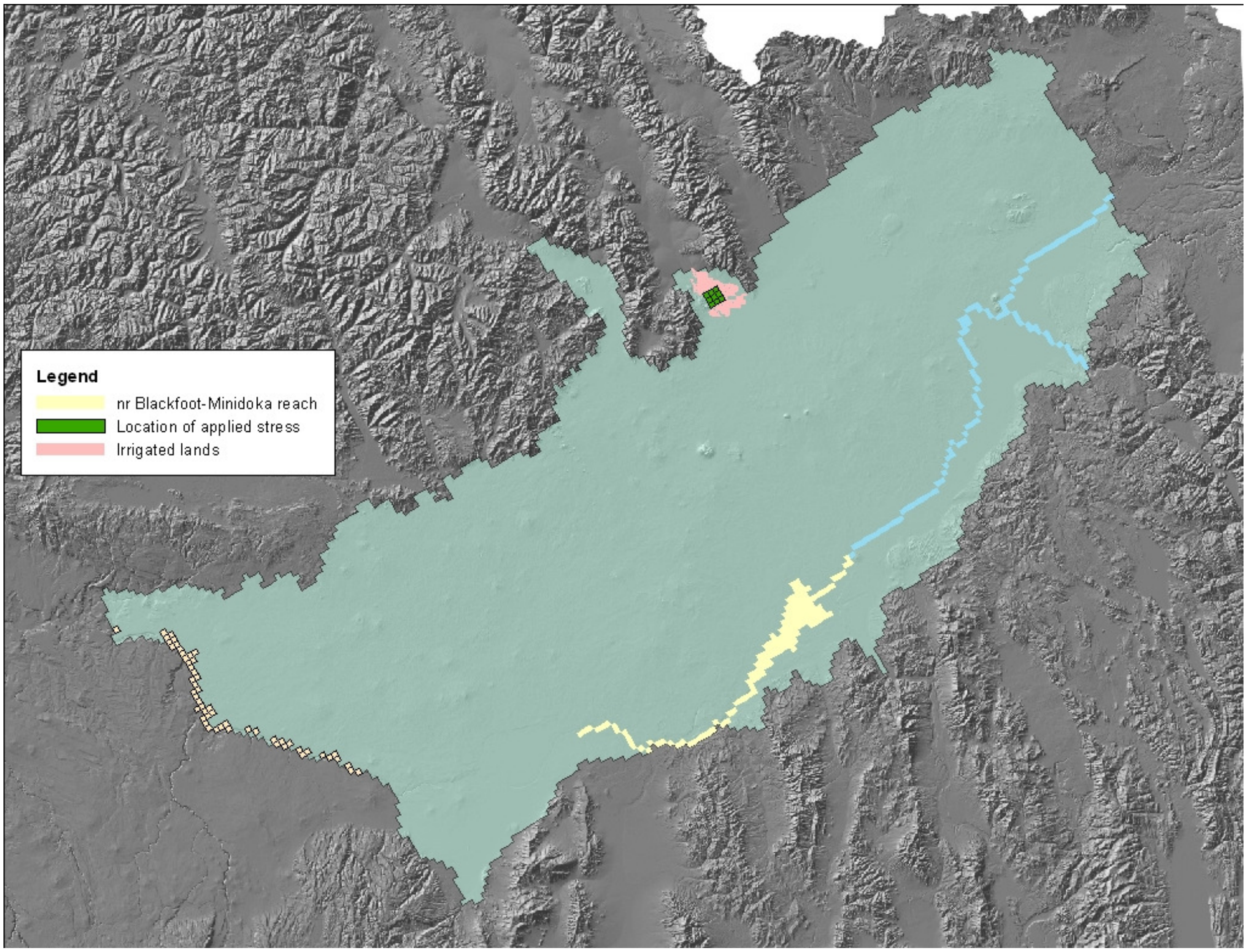
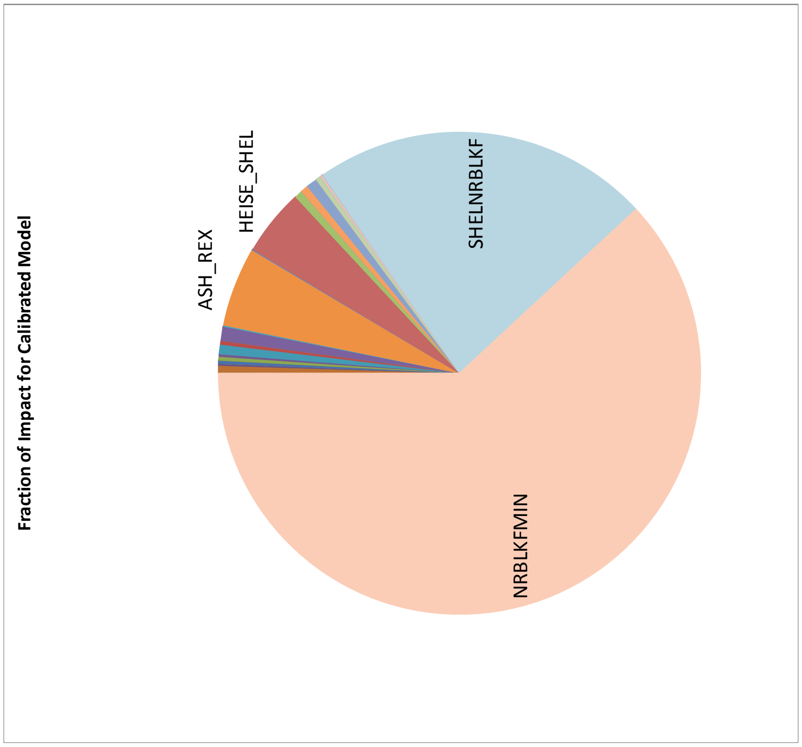
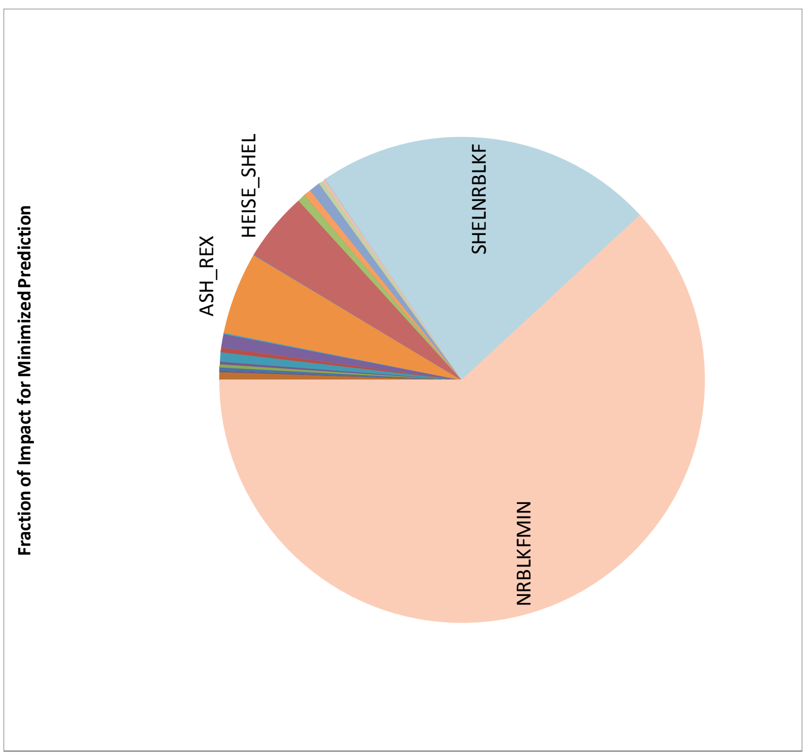


Impact of Water District 33 on nr Blackfoot-Minidoka using calibration run E120116A008.

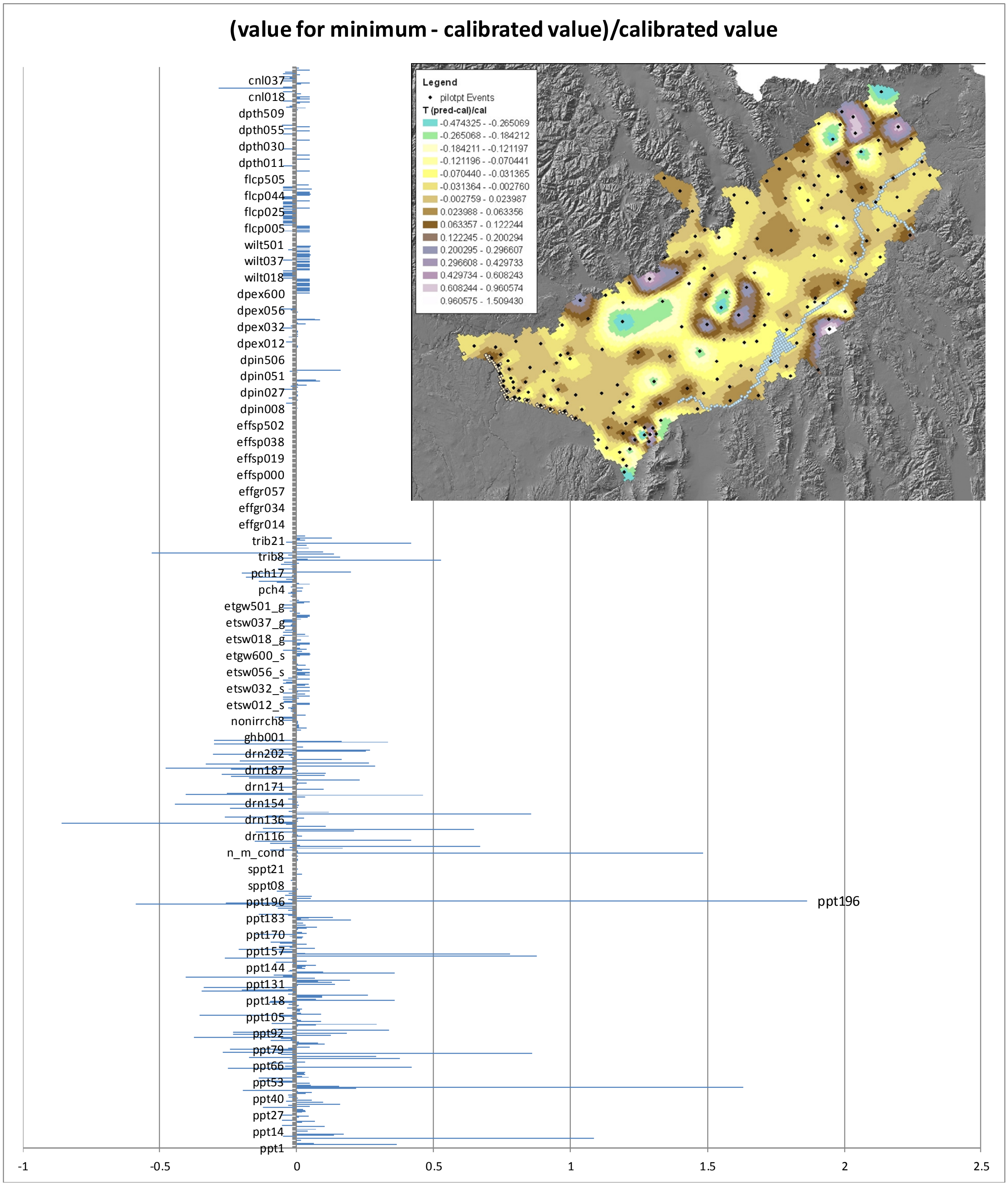


Impact of Water District 33 on nr Blackfoot-Minidoka using calibration run E120116A008.

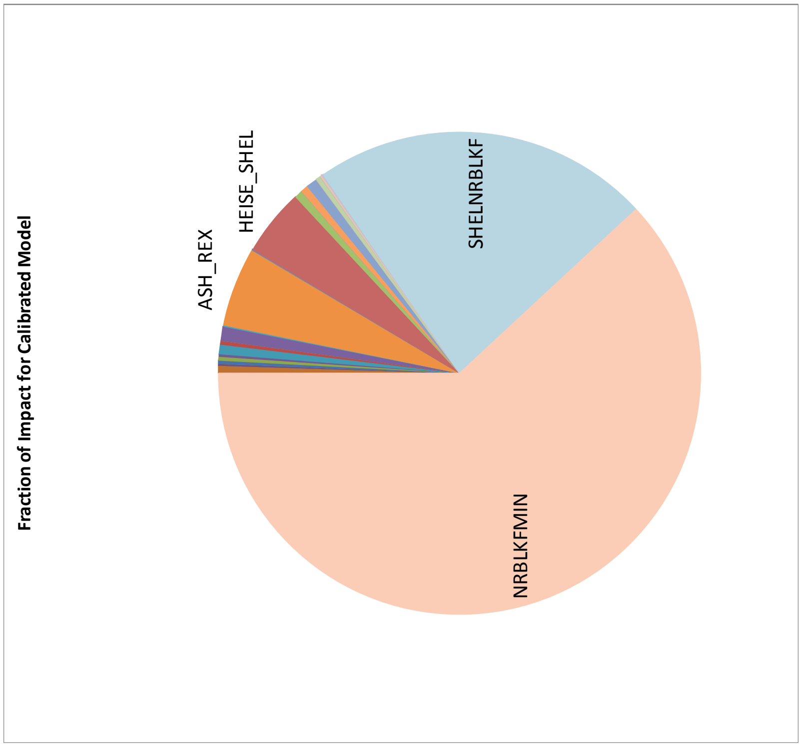


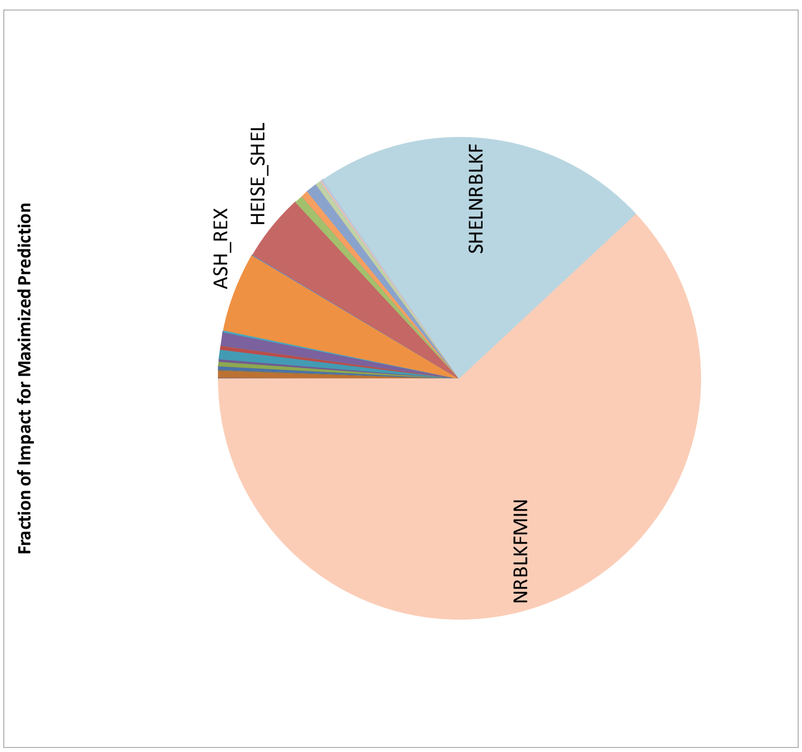


Impact of Water District 33 on nr Blackfoot-Minidoka using calibration run E120116A008.

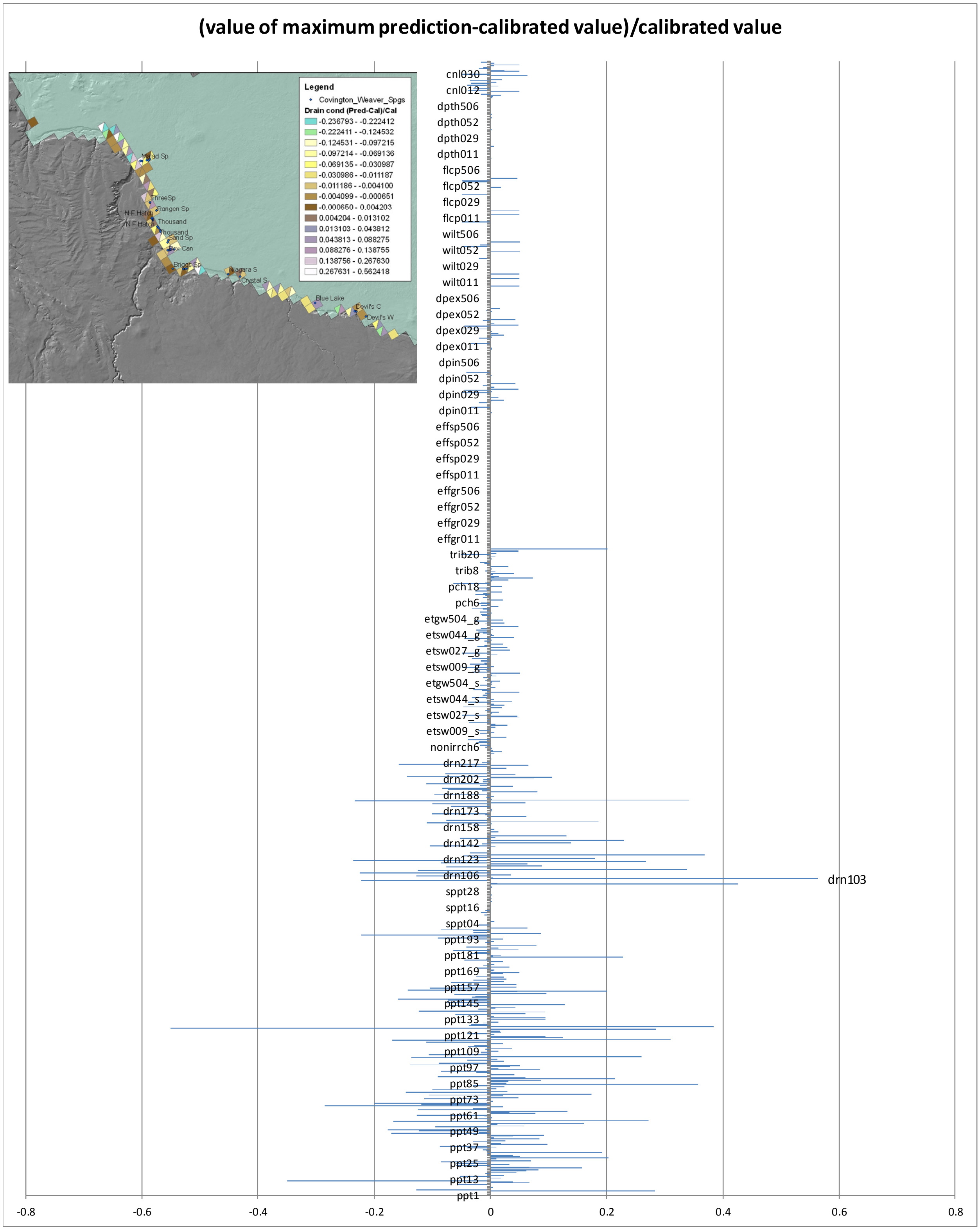


Impact of Water District 33 on nr Blackfoot-Minidoka using calibration run E120116A008.

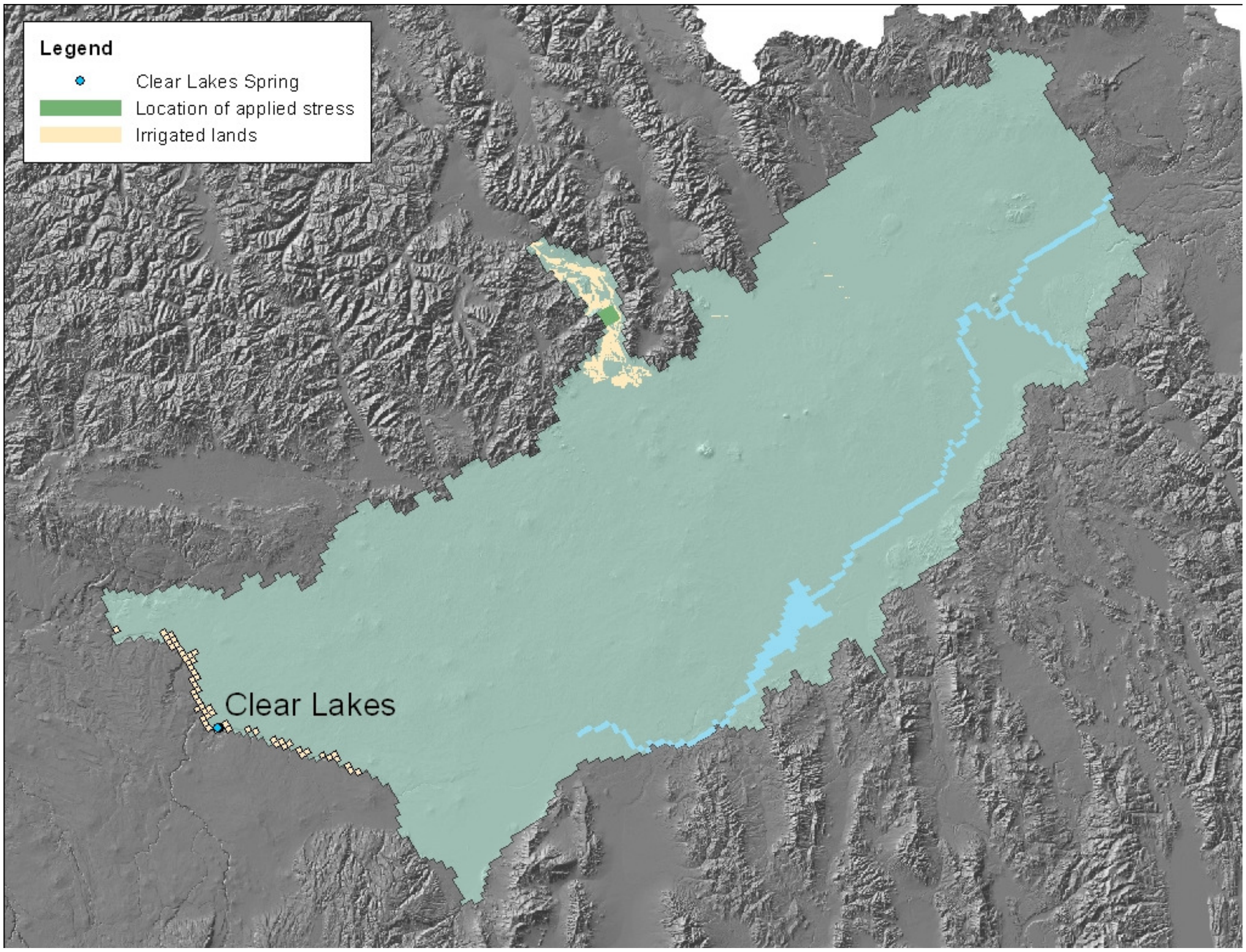




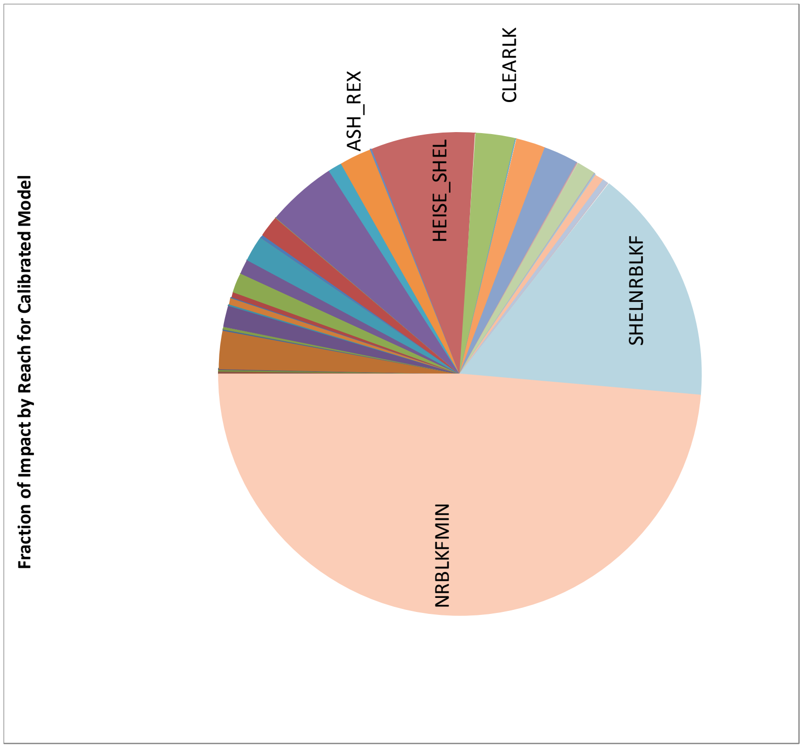
Impact of Water District 33 on nr Blackfoot-Minidoka using calibration run E120116A008.

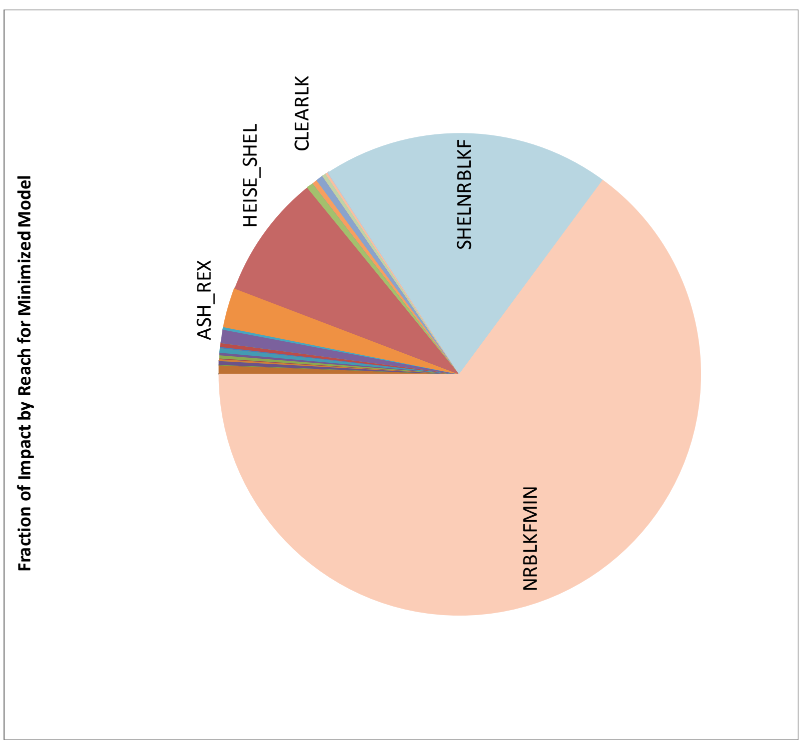


Impact of Water District 34 on Clear Lakes using calibration run E110712A001.



Impact of Water District 34 on Clear Lakes using calibration run E110712A001.





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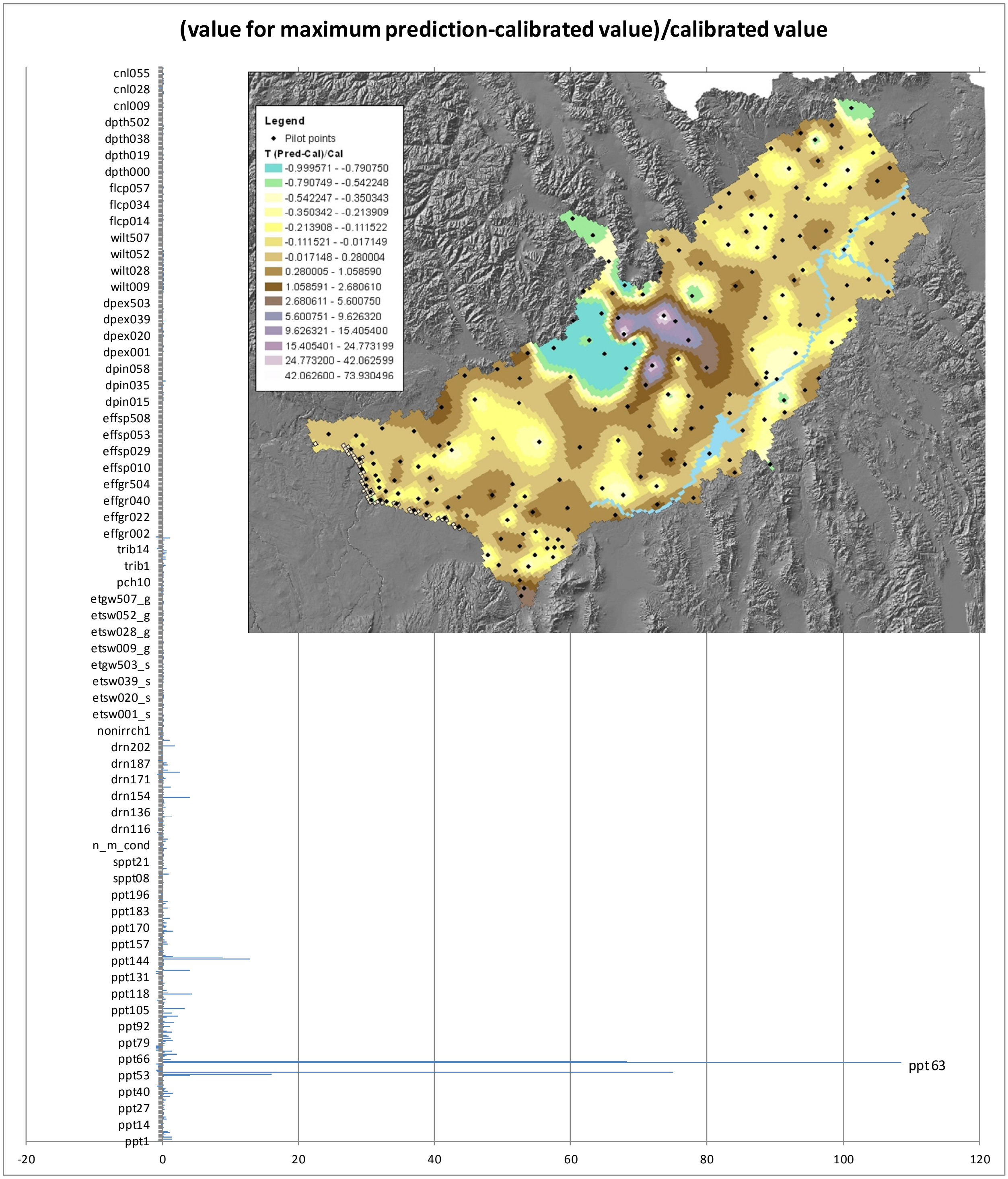
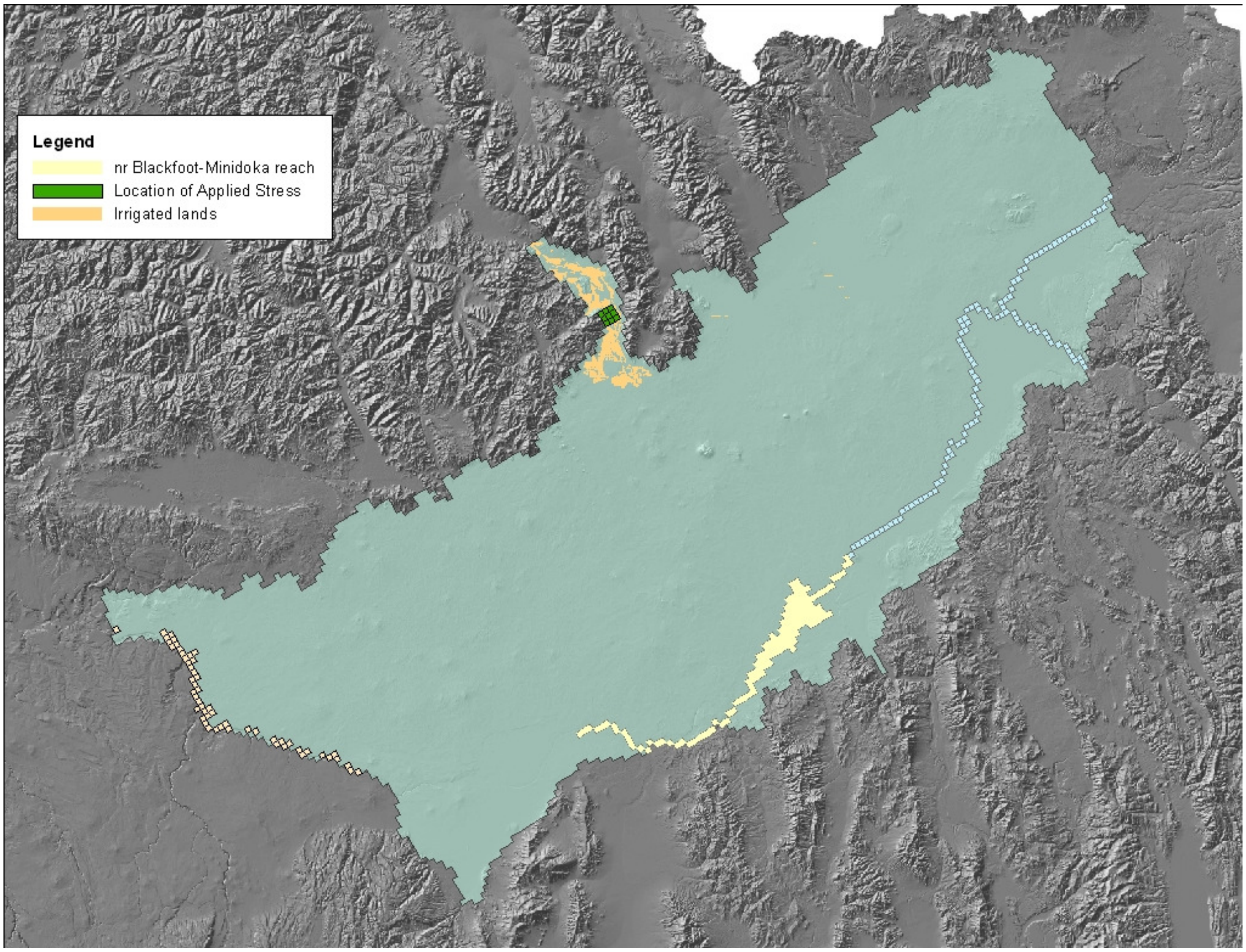
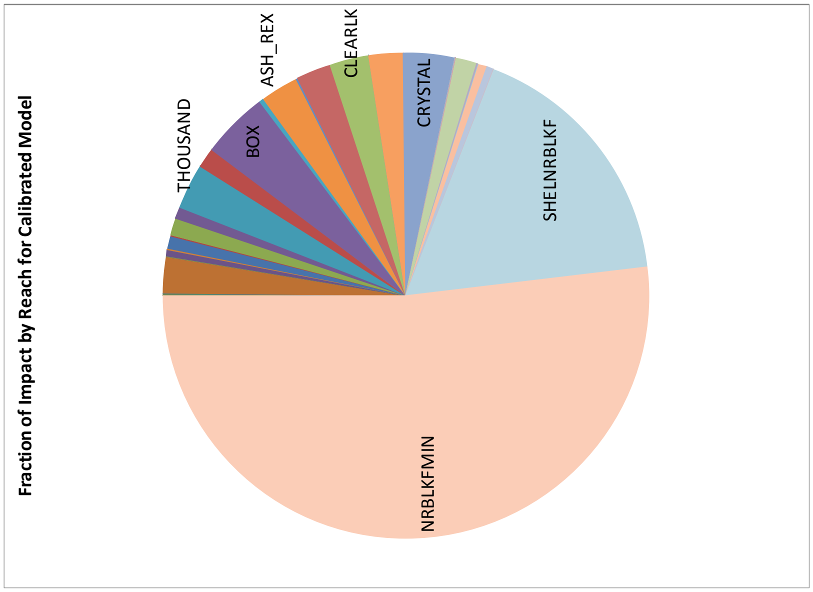
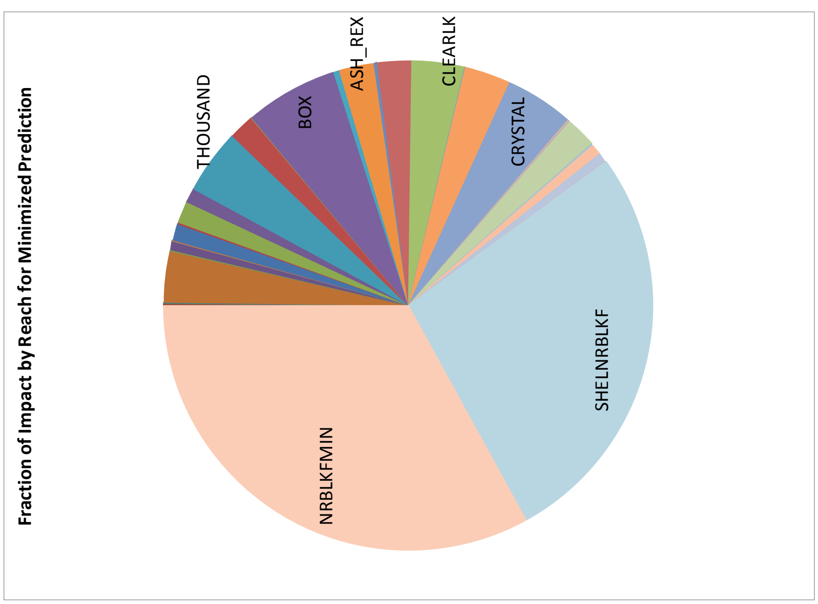


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

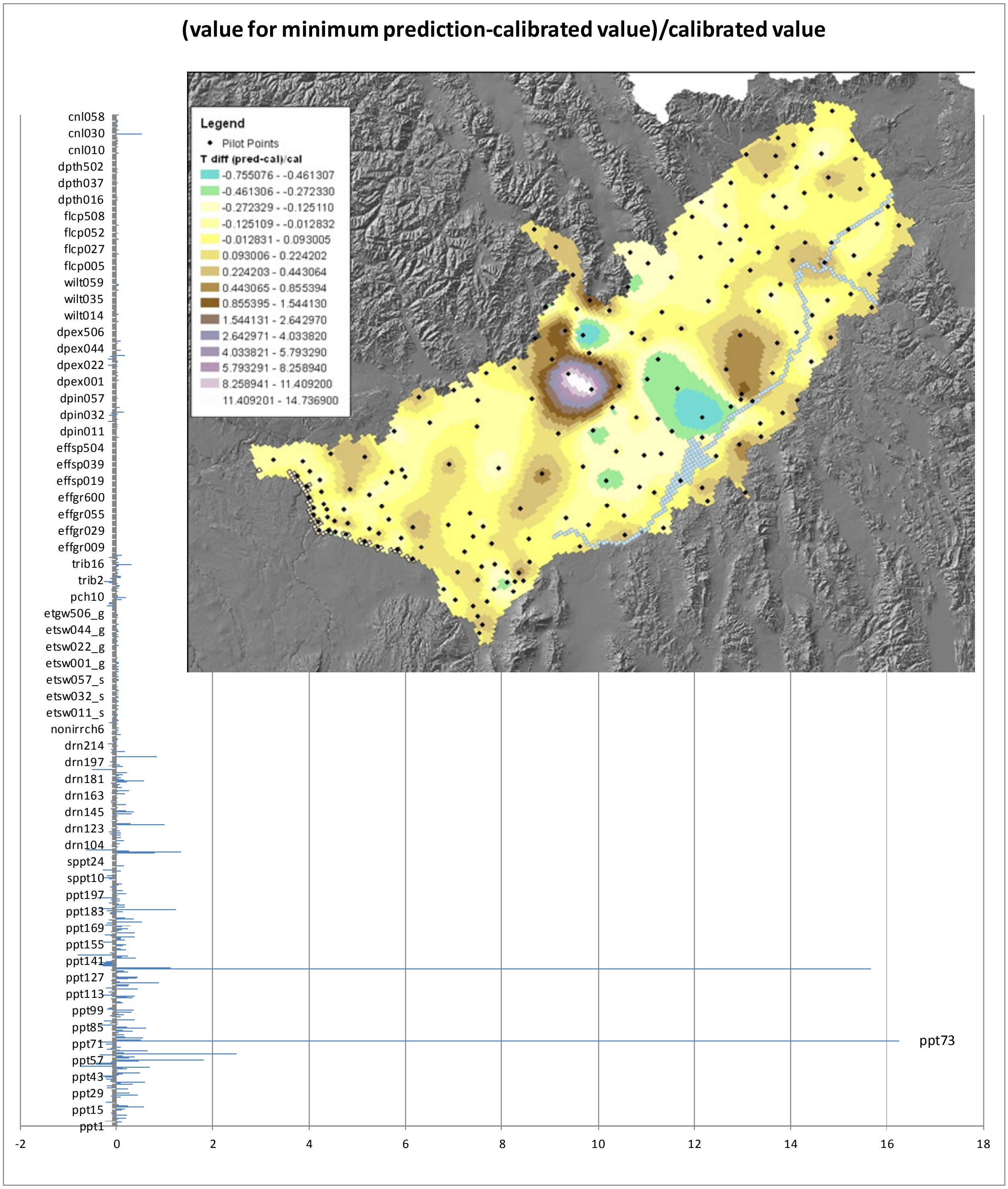


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

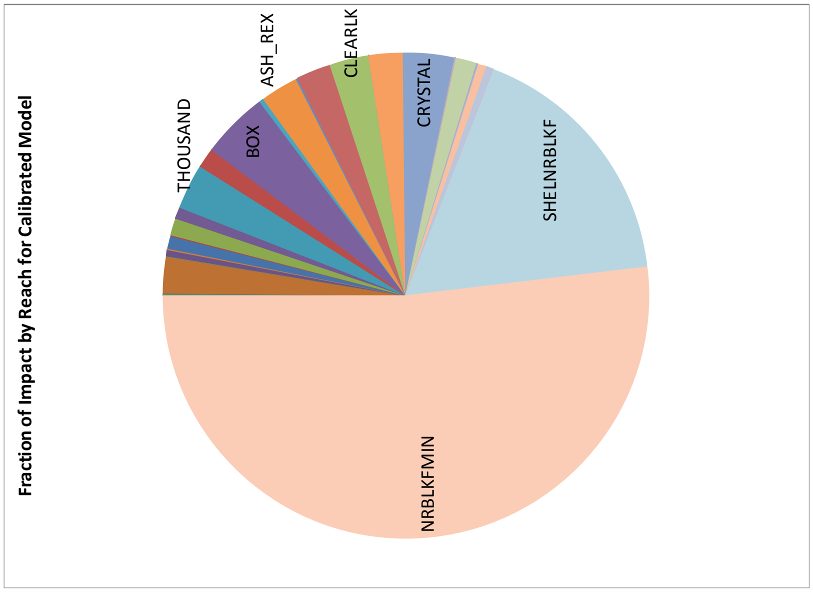


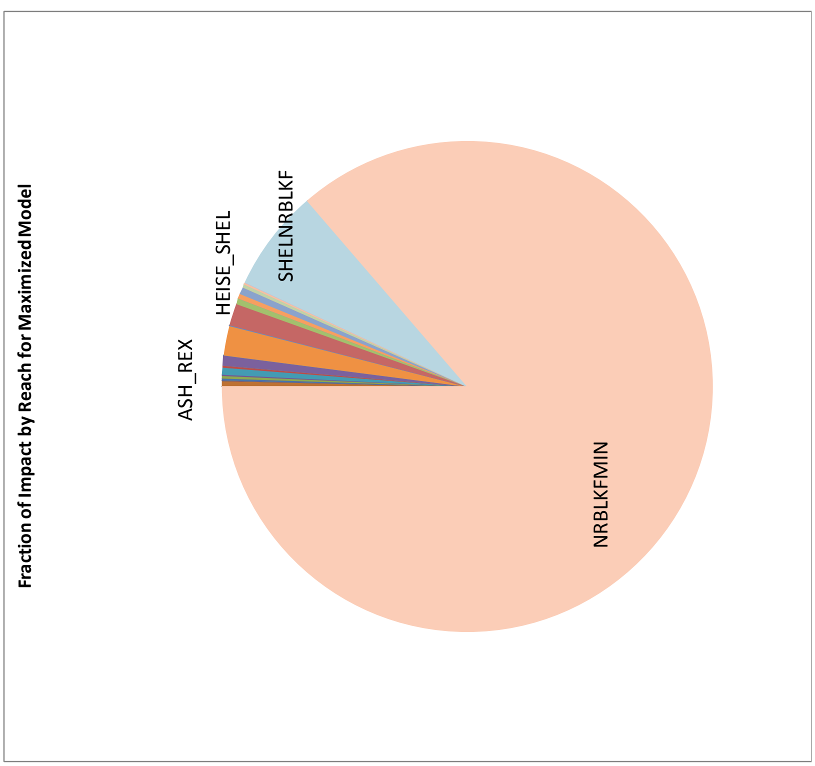


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

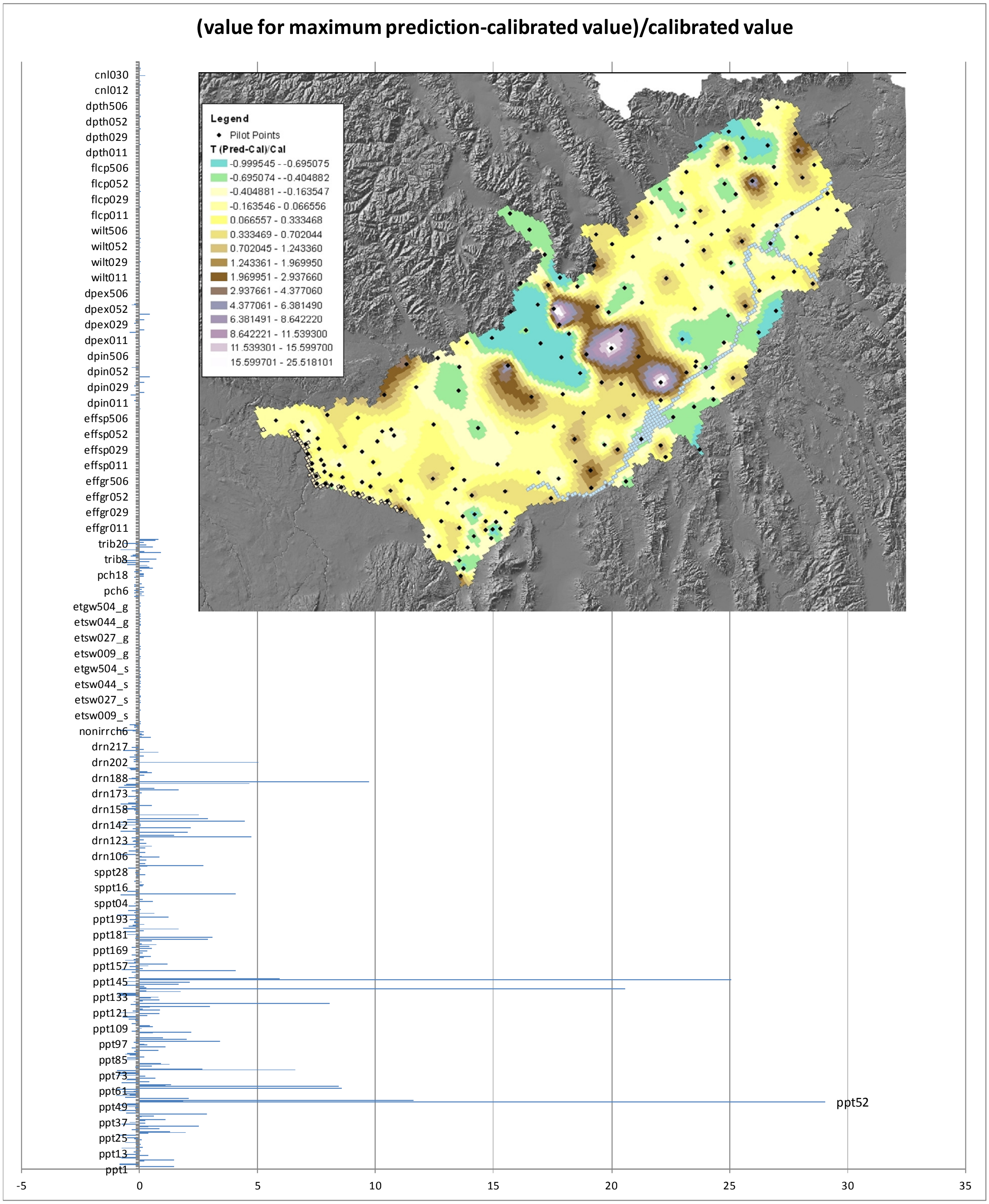


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

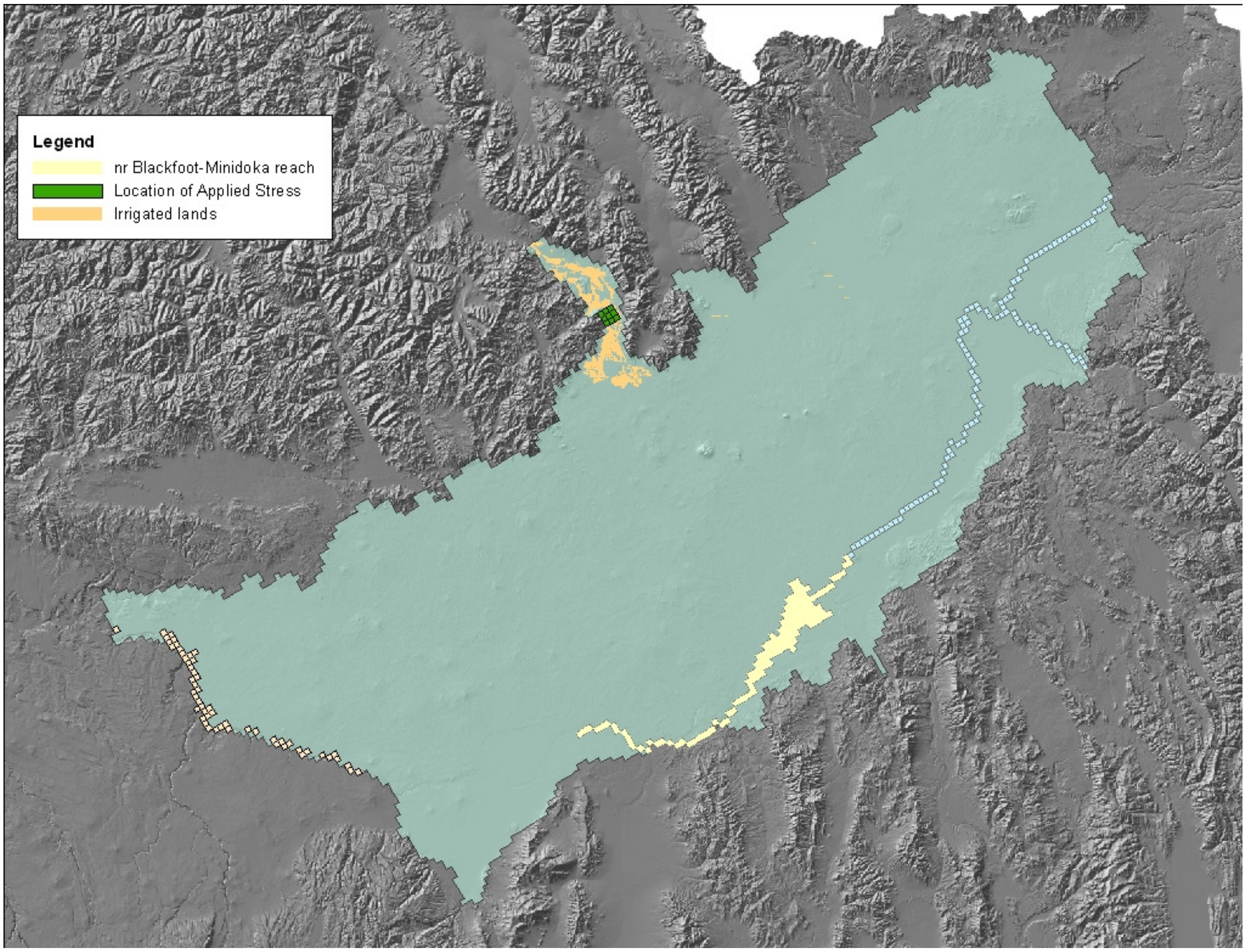




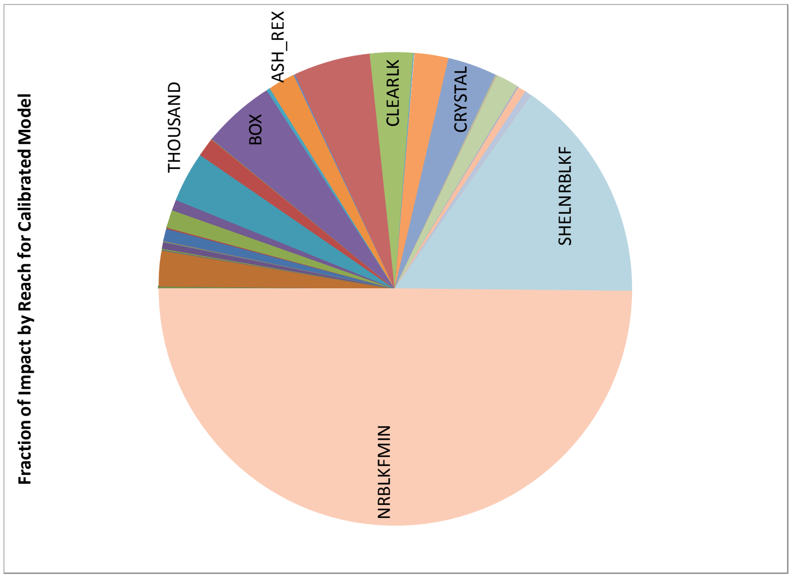
Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

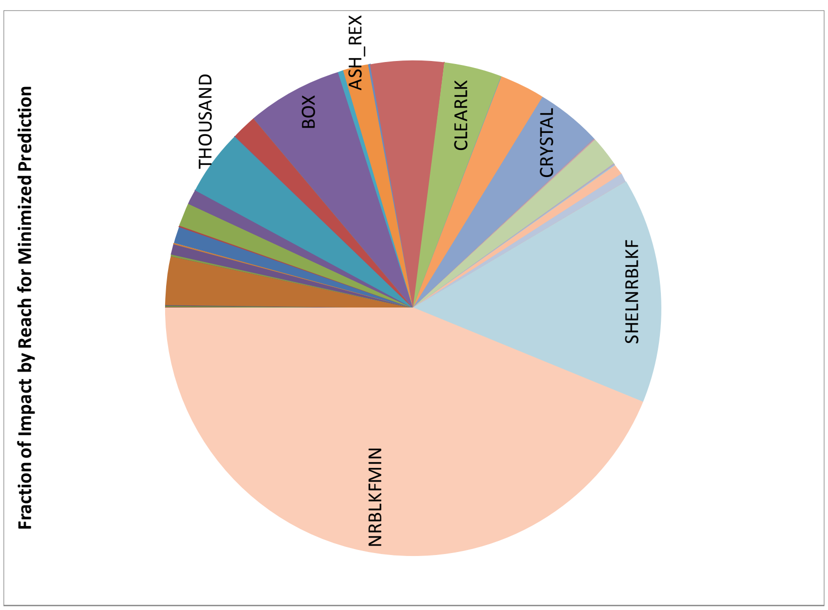


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E121025A001.



Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E121025A001.





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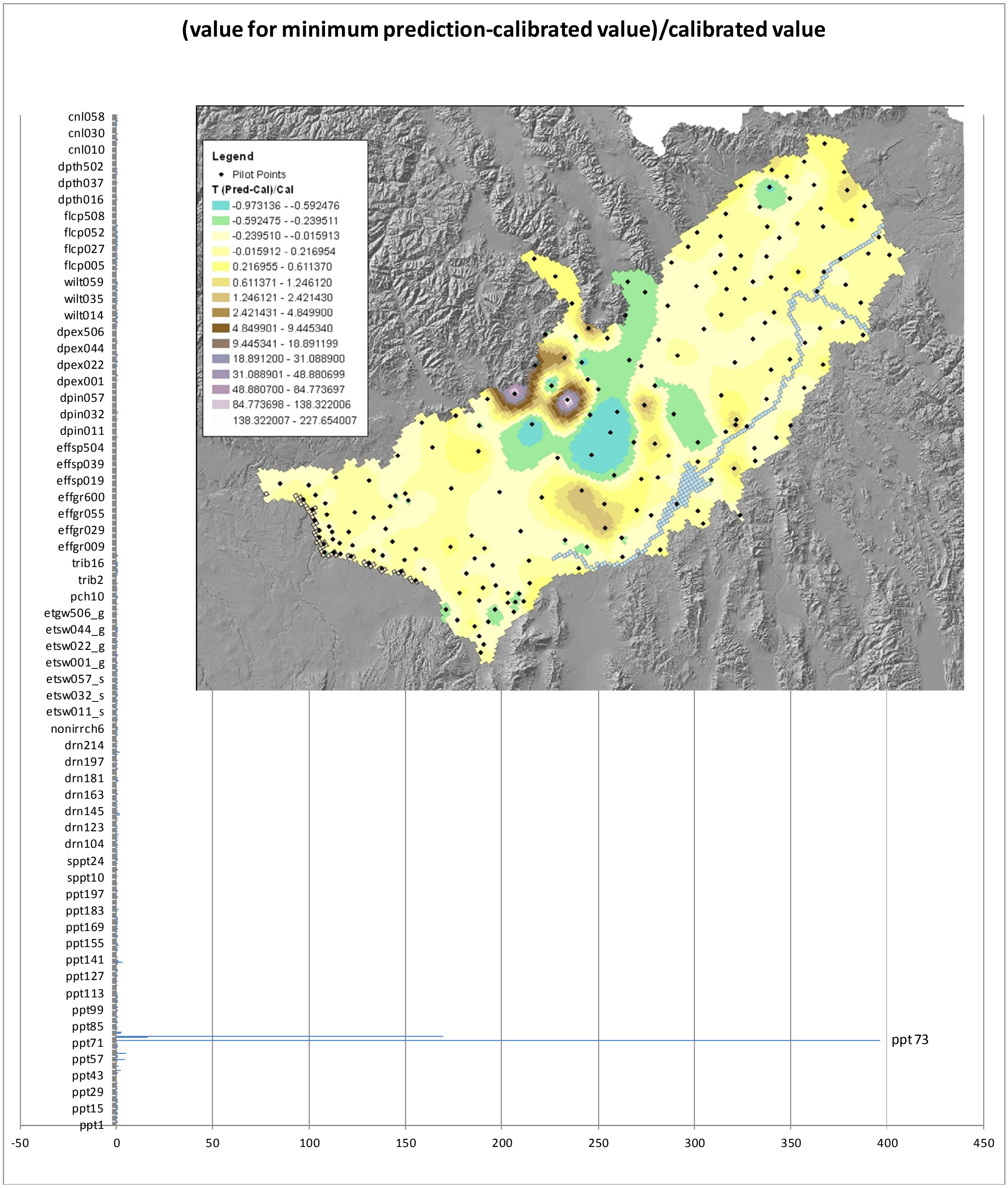

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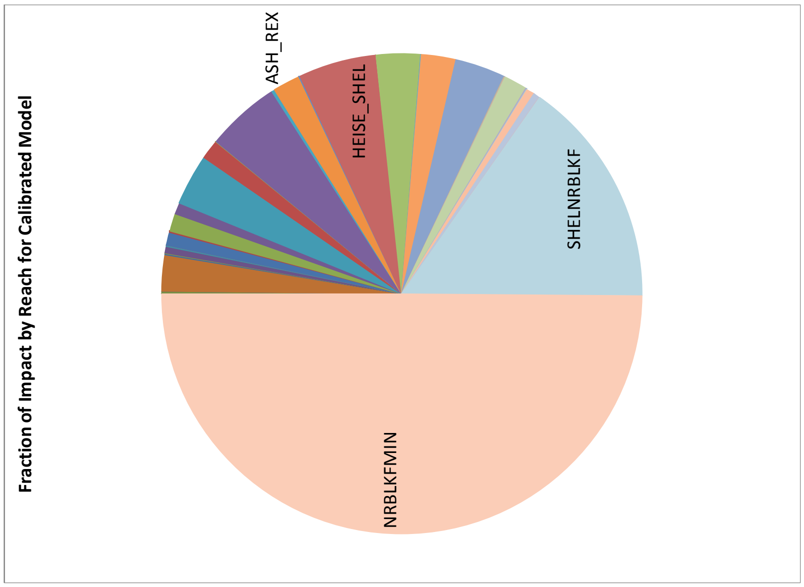
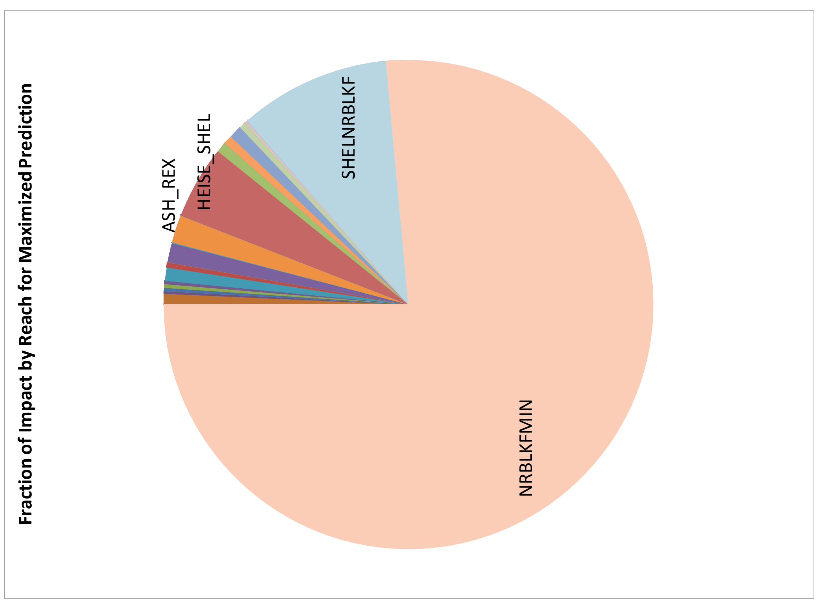
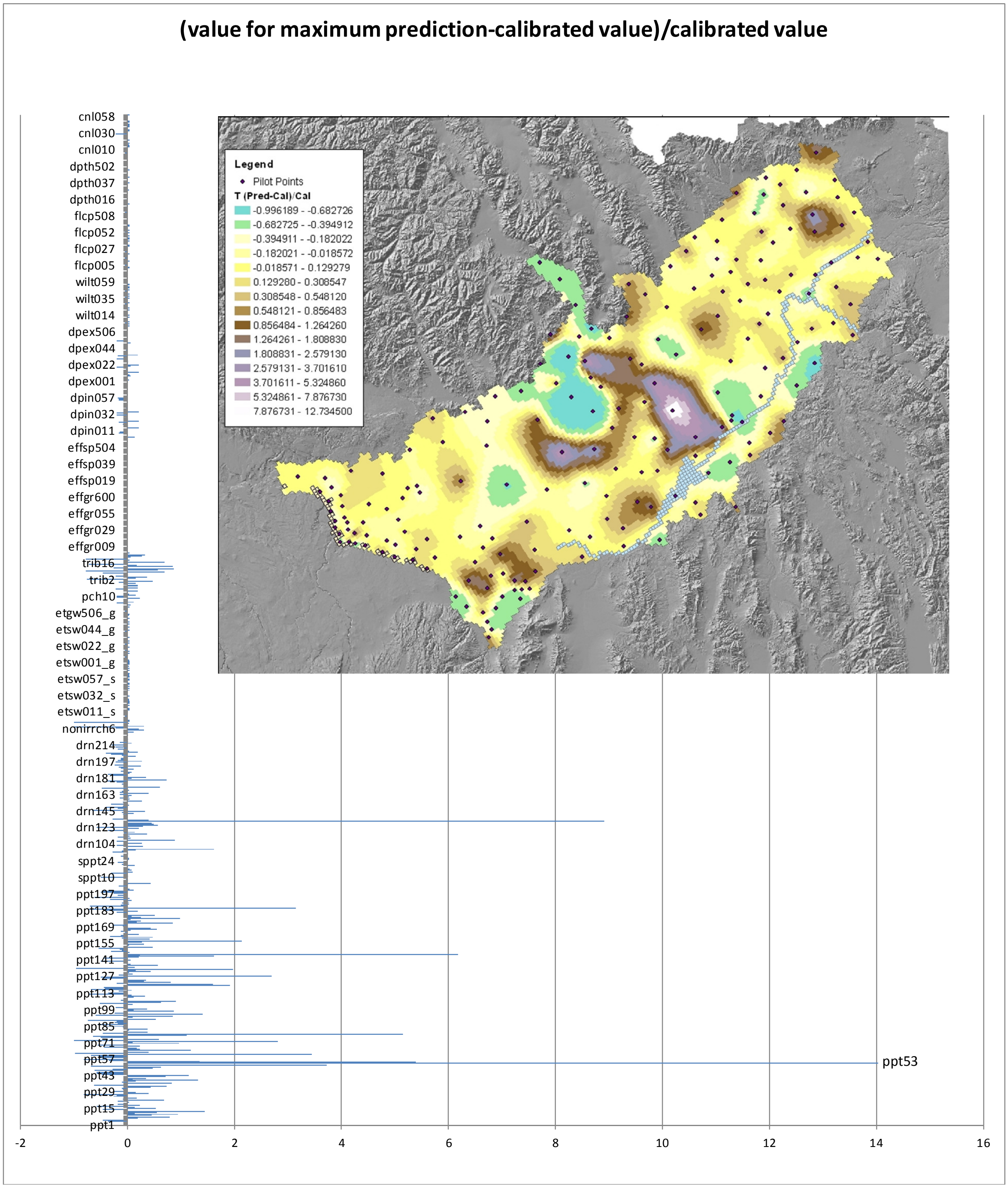
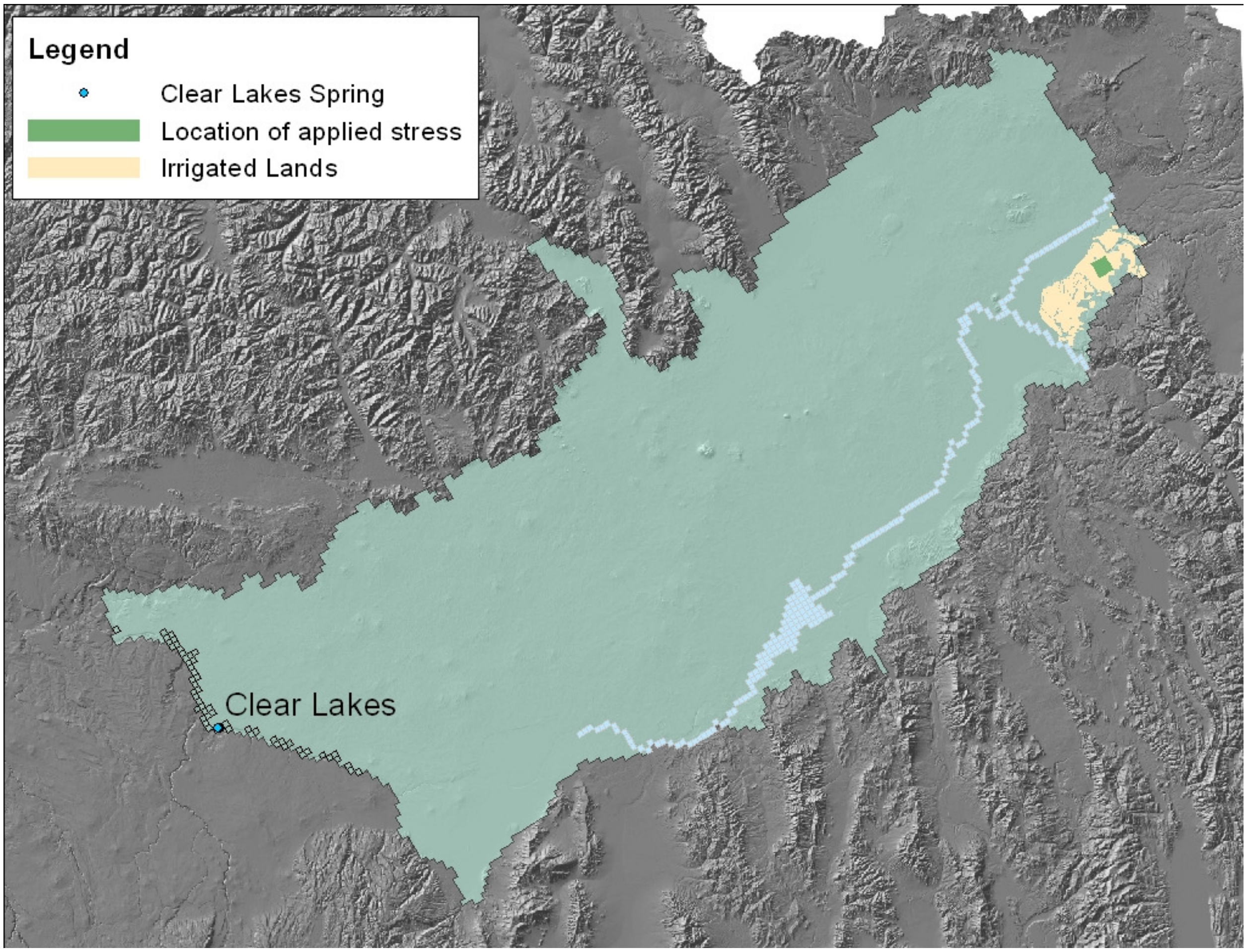




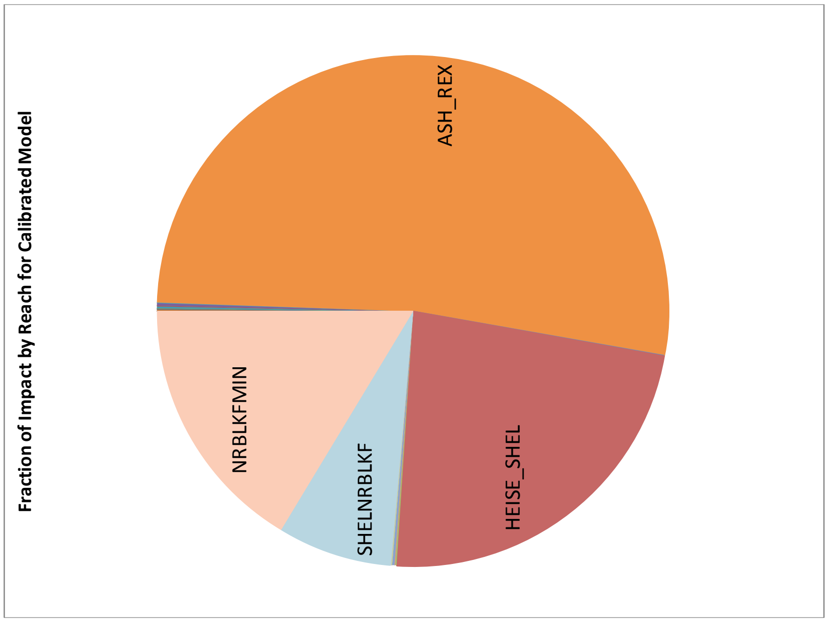
Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E121025A001.

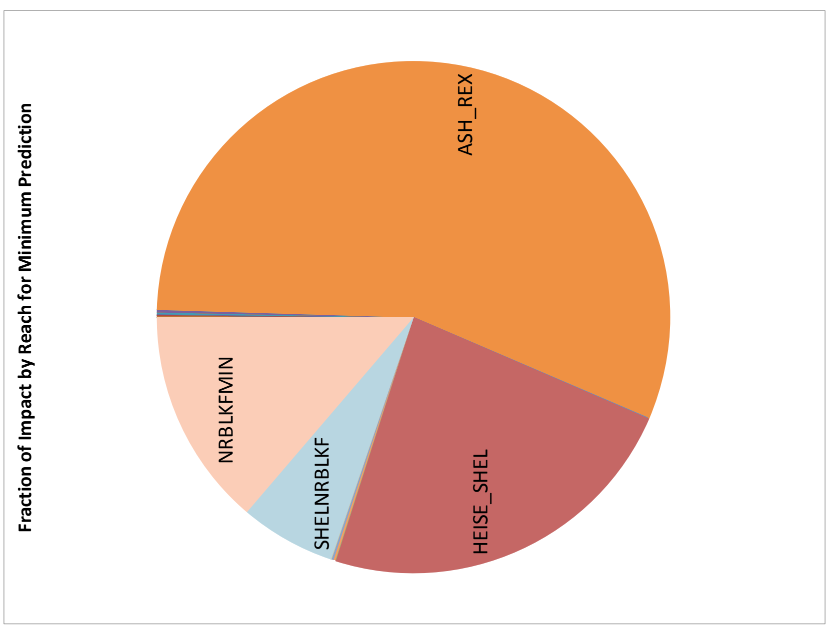


Impact of Water District 99 (Rexburg Bench) on near Clear Lakes using calibration run E120116A008.

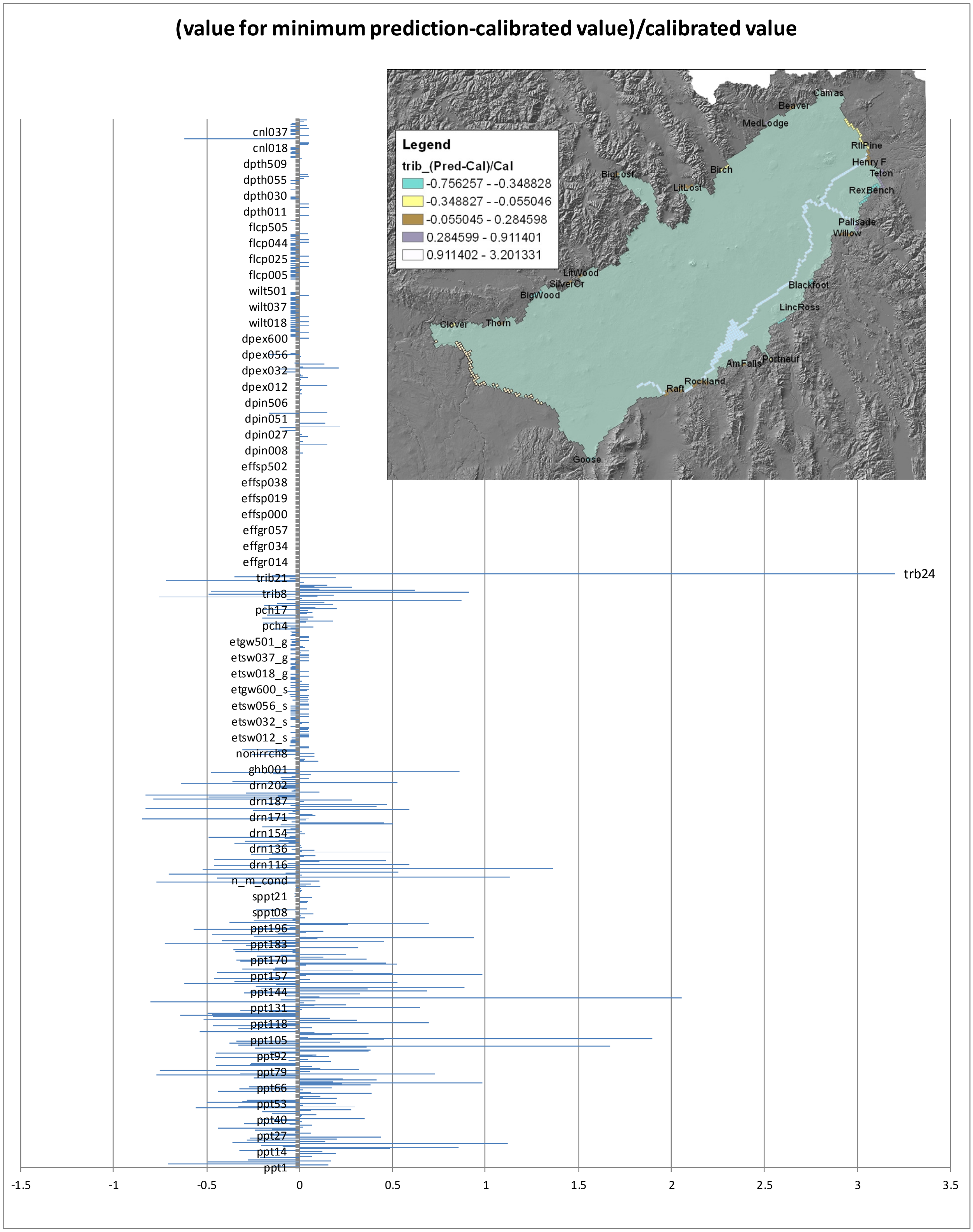


Impact of Water District 99 (Rexburg Bench) on near Clear Lakes using calibration run E120116A008.

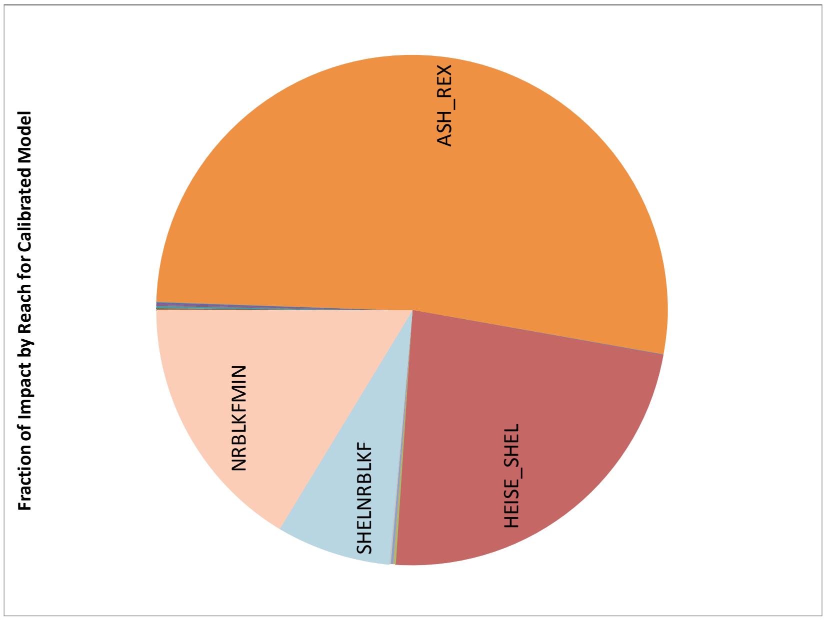


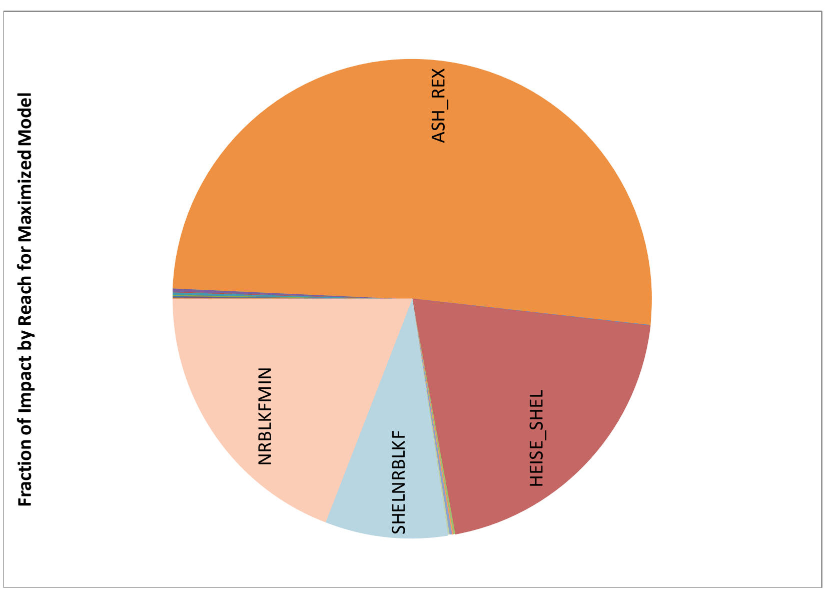


Impact of Water District 99 (Rexburg Bench) on near Clear Lakes using calibration run E120116A008.

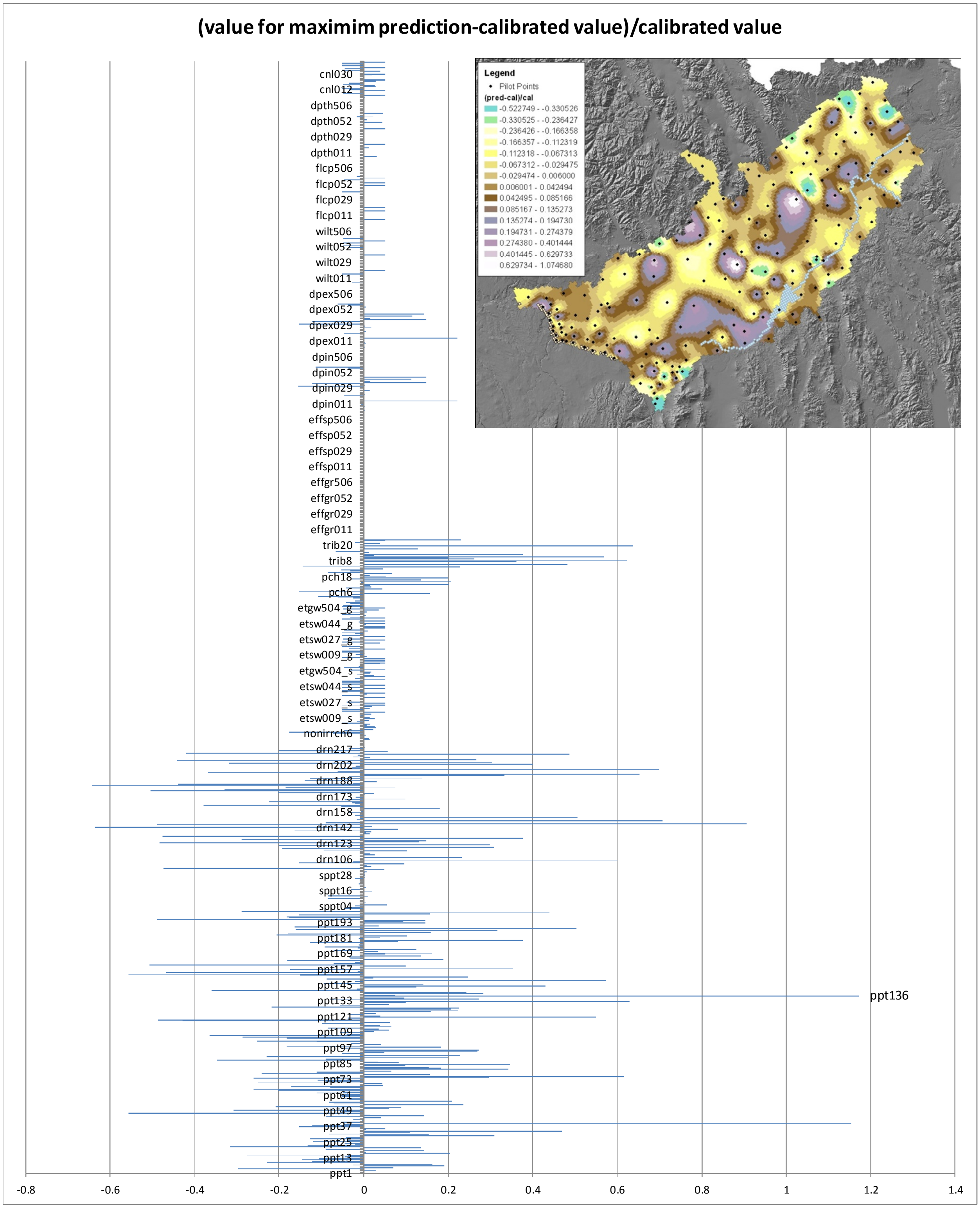


Impact of Water District 99 (Rexburg Bench) on near Clear Lakes using calibration run E120116A008.

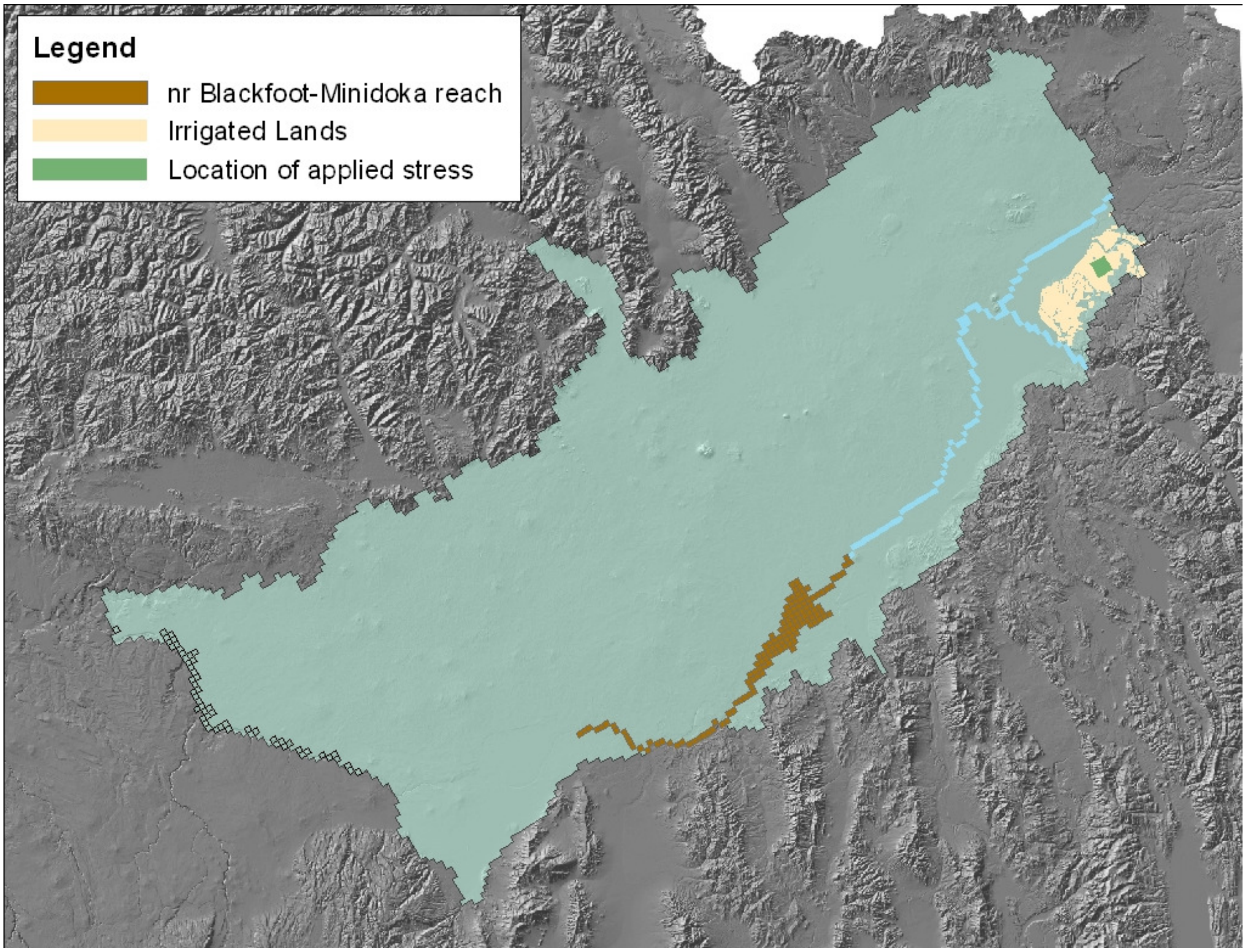




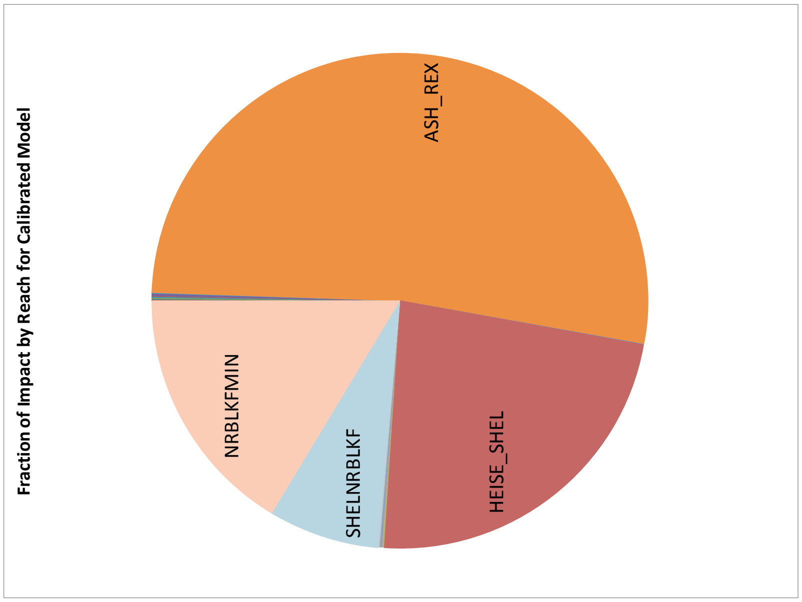
Impact of Water District 99 (Rexburg Bench) on near Clear Lakes using calibration run E120116A008.

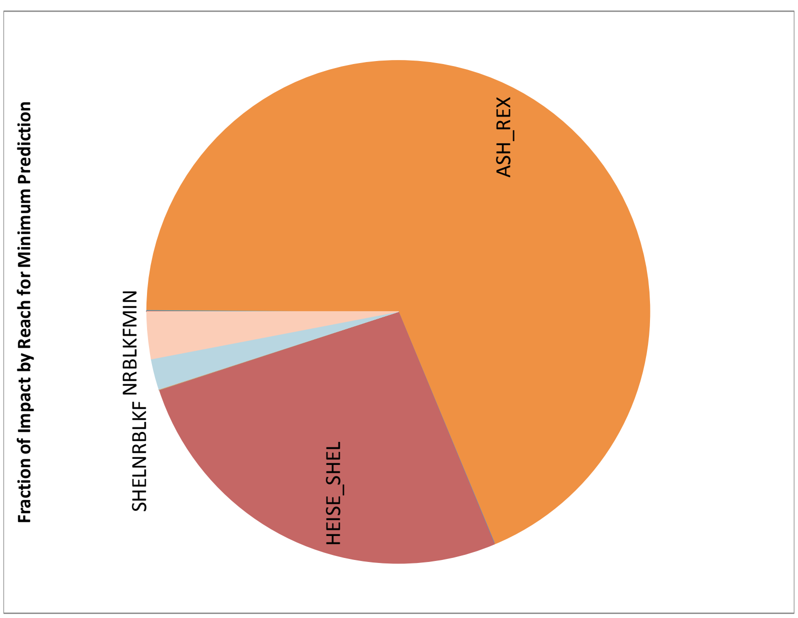


Impact of Water District 99 (Rexburg Bench) on near Blackfoot-Minidoka using calibration run E120116A008.

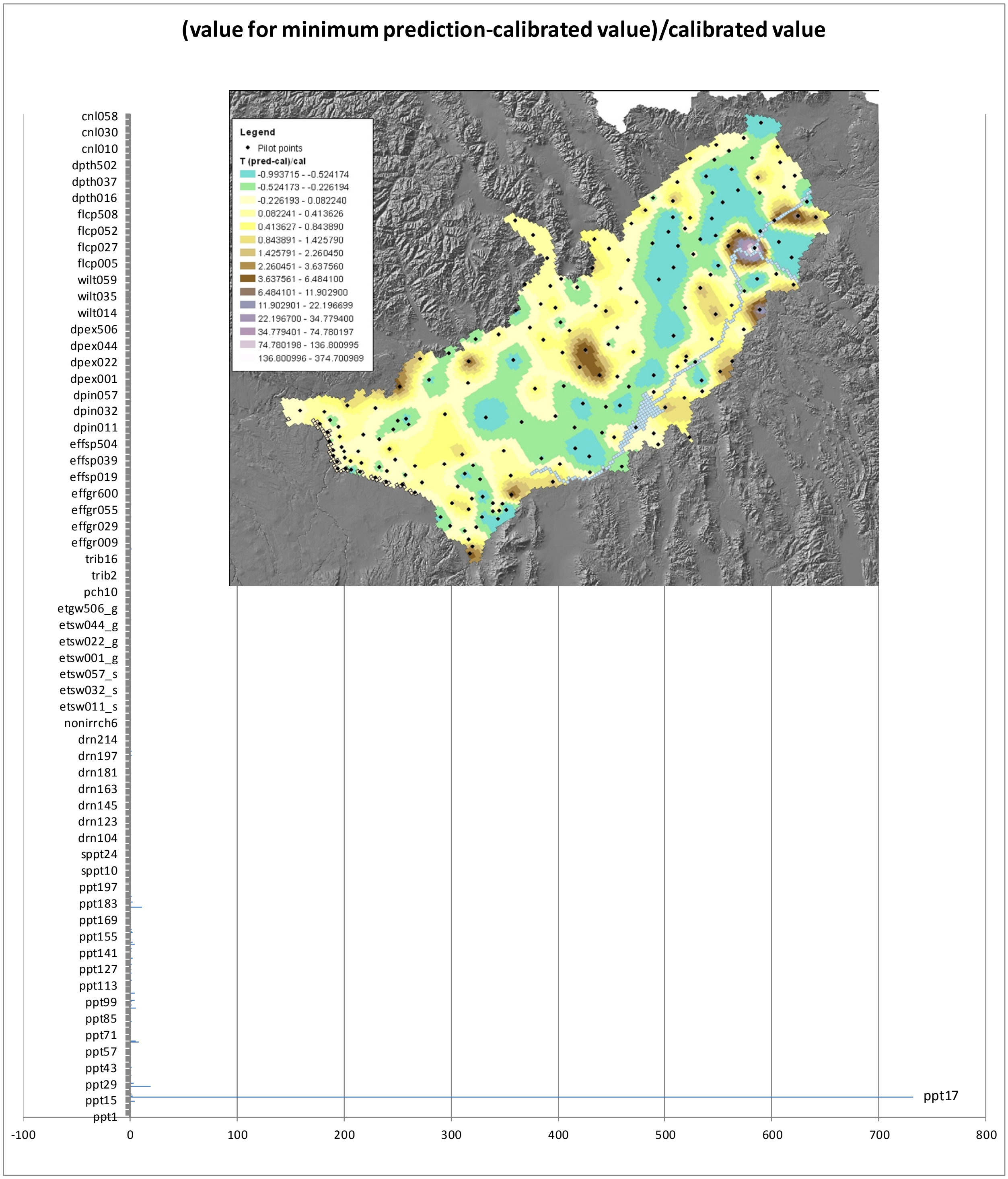


Impact of Water District 99 (Rexburg Bench) on near Blackfoot-Minidoka using calibration run E120116A008.

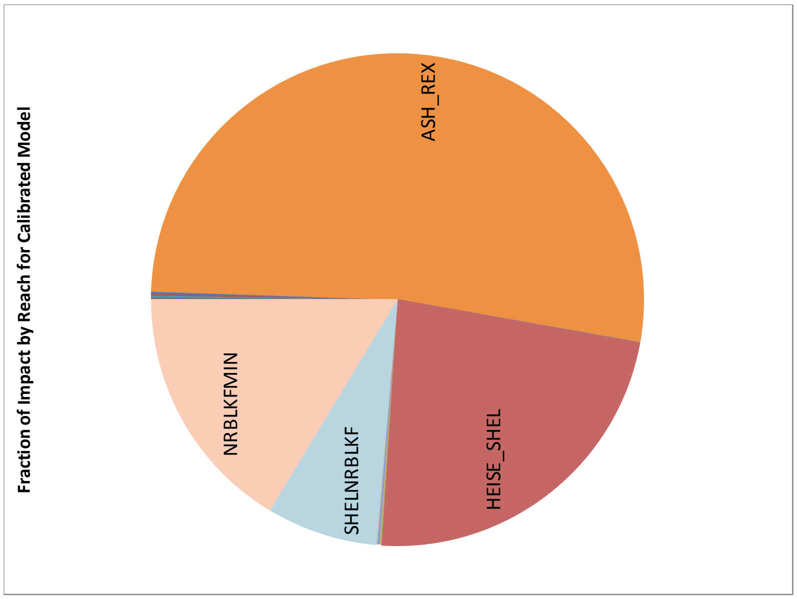


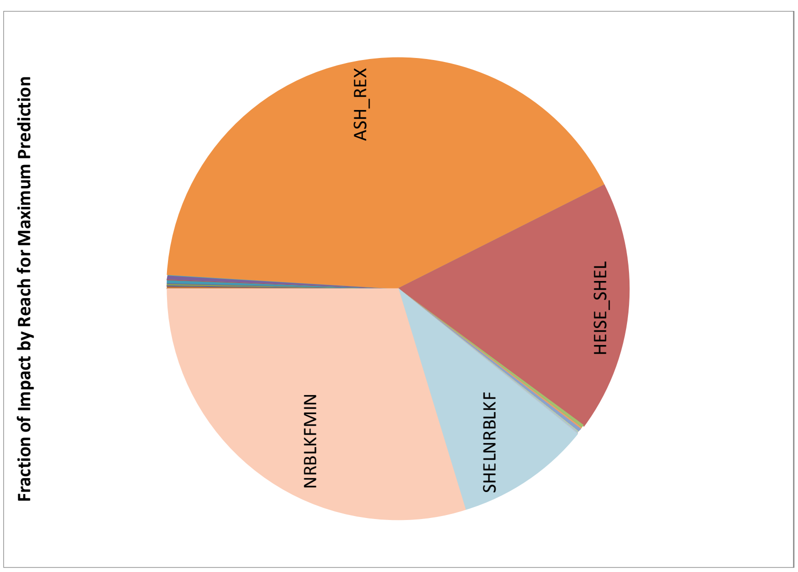


Impact of Water District 99 (Rexburg Bench) on near Blackfoot-Minidoka using calibration run E120116A008.

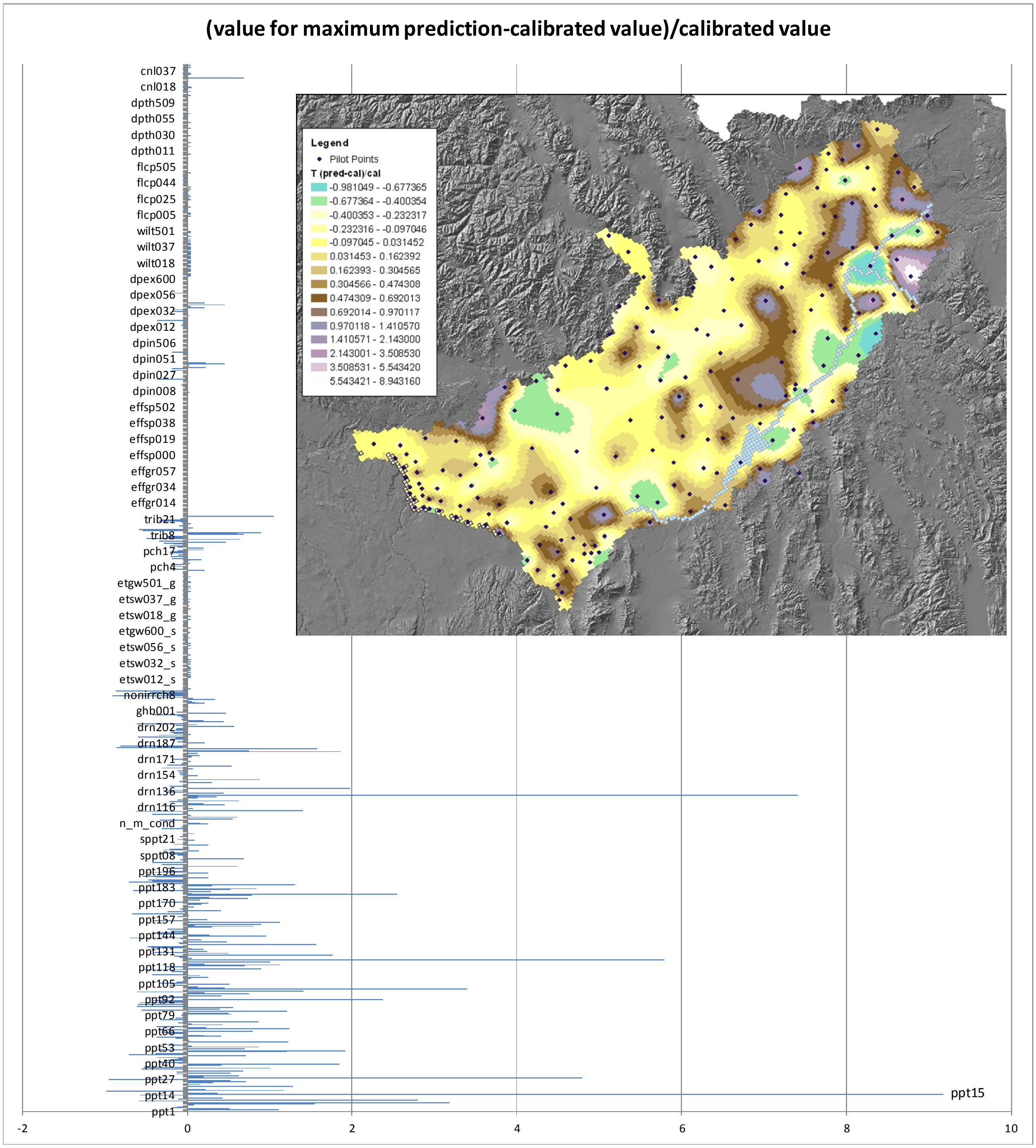


Impact of Water District 99 (Rexburg Bench) on near Blackfoot-Minidoka using calibration run E120116A008.

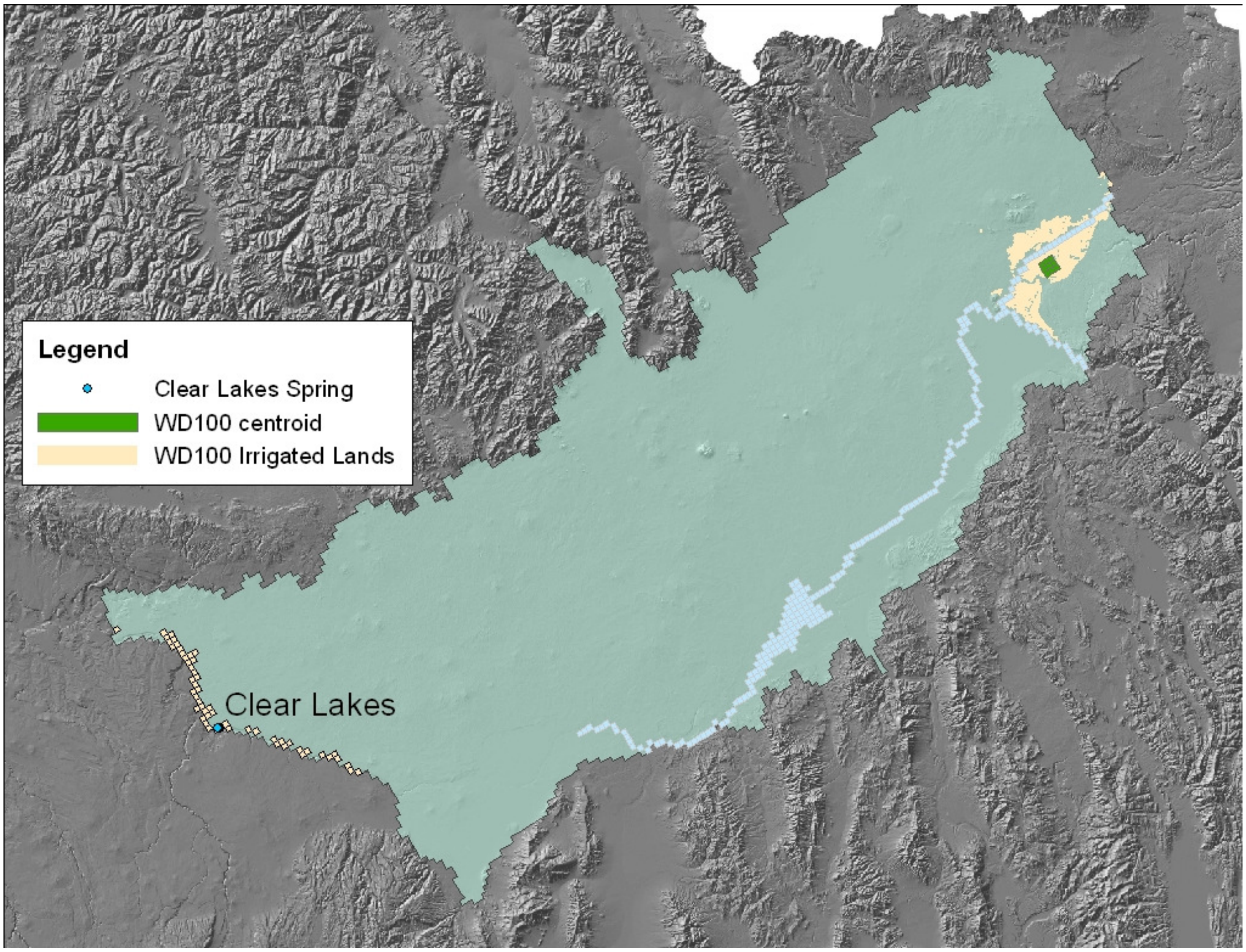




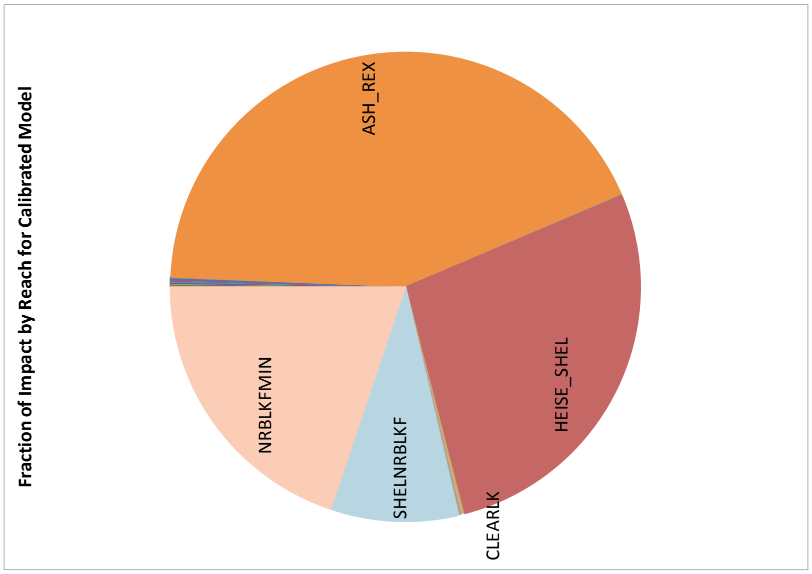
Impact of Water District 99 (Rexburg Bench) on near Blackfoot-Minidoka using calibration run E120116A008.

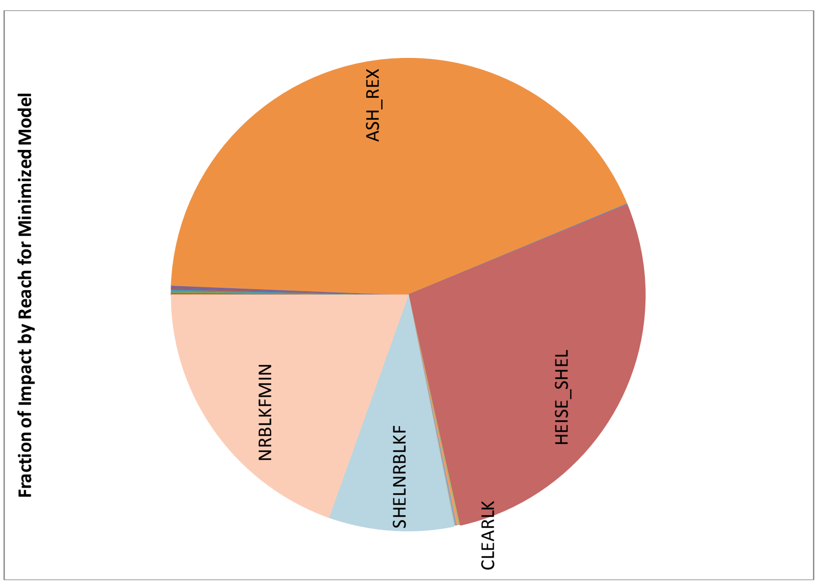


Impact of Water District 100 on Clear Lakes Spring using calibration run E120116A008.

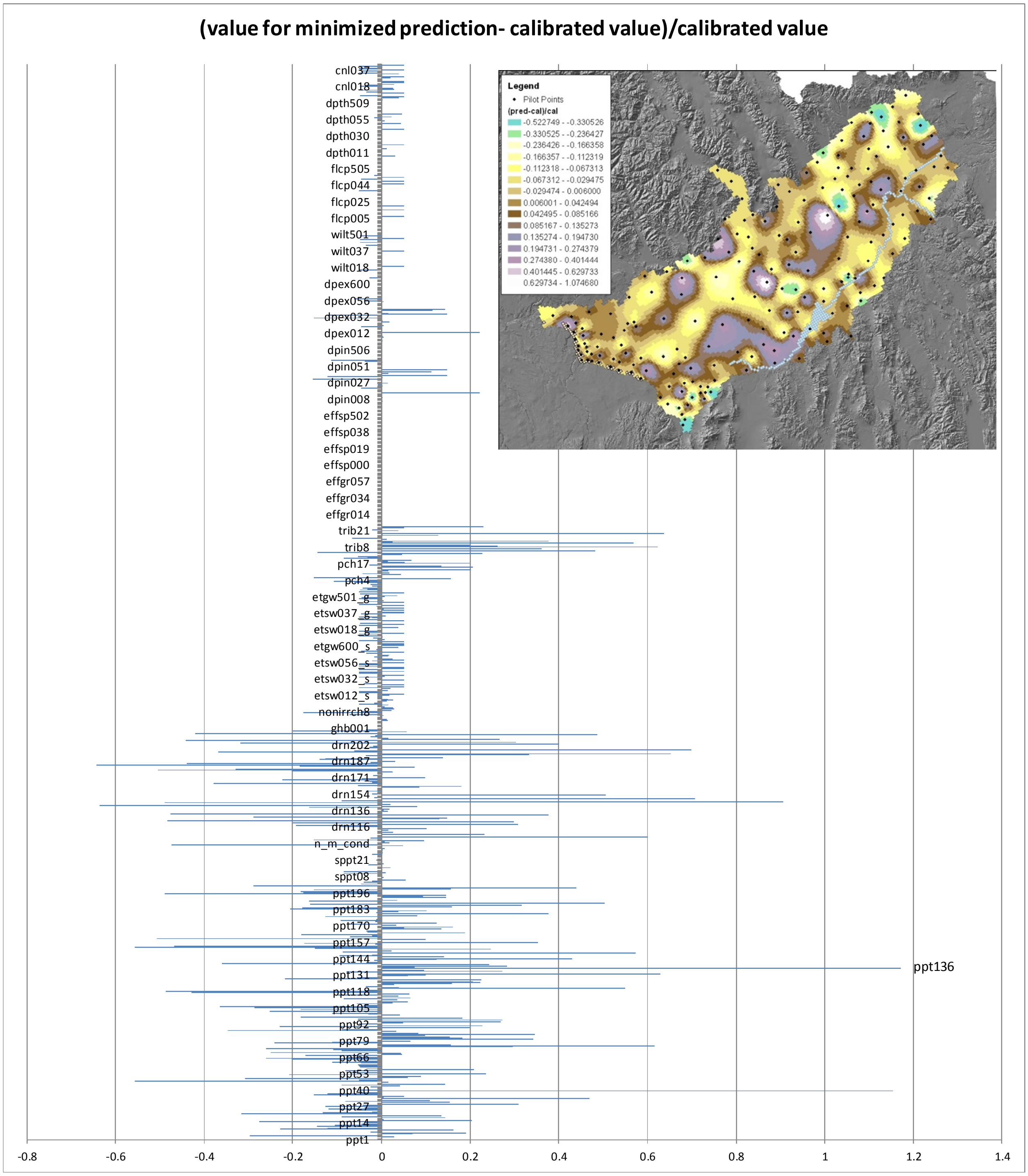


Impact of Water District 100 on Clear Lakes Spring using calibration run E120116A008.

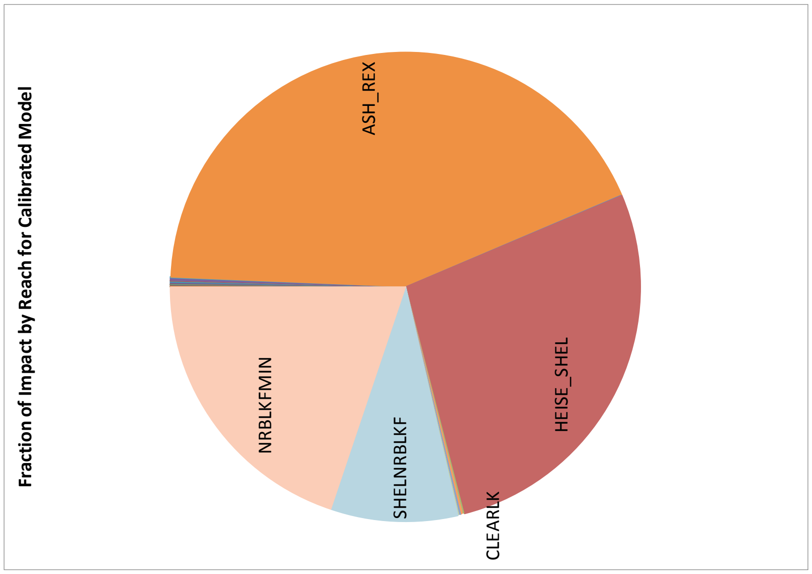


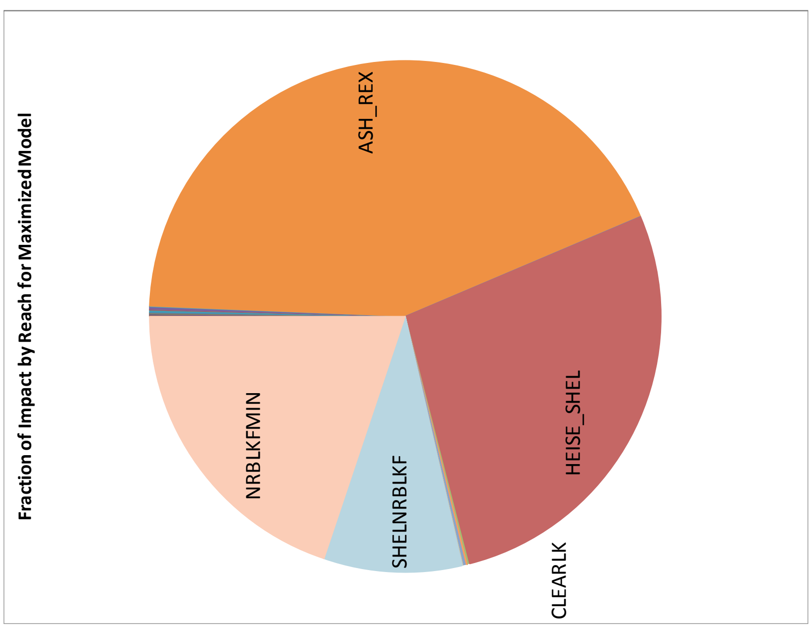


Impact of Water District 100 on Clear Lakes Spring using calibration run E120116A008.

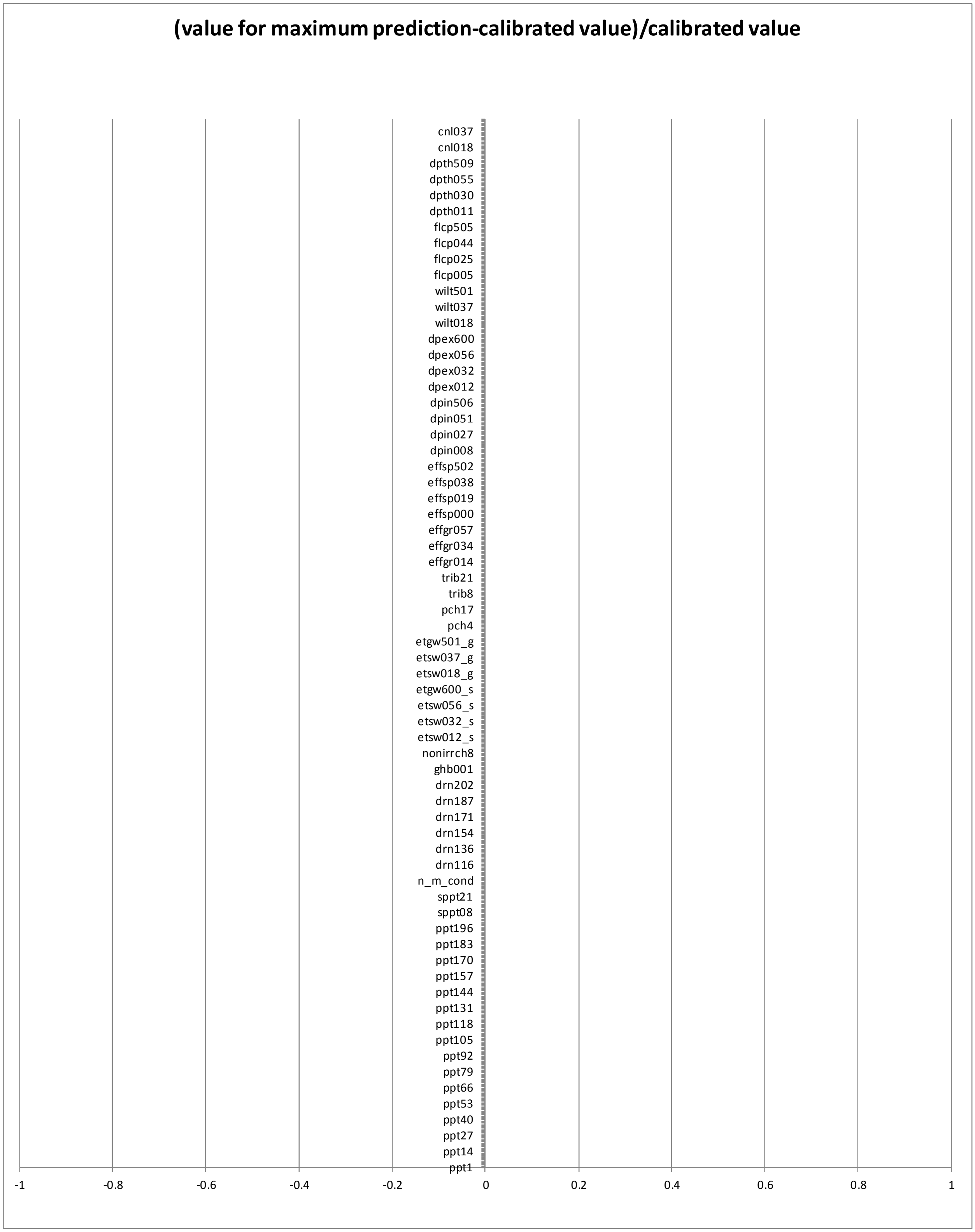


Impact of Water District 100 on Clear Lakes Spring using calibration run E120116A008.

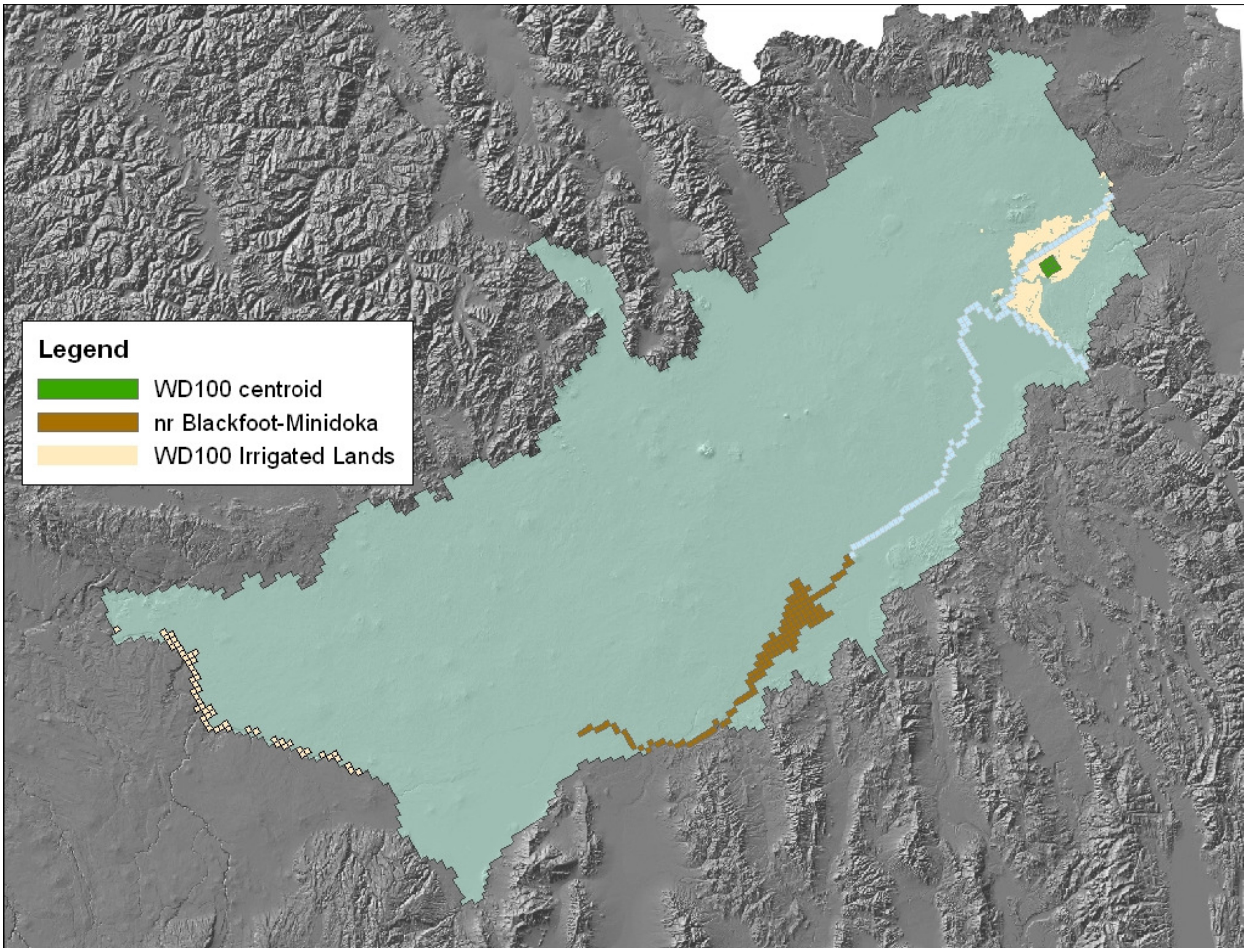




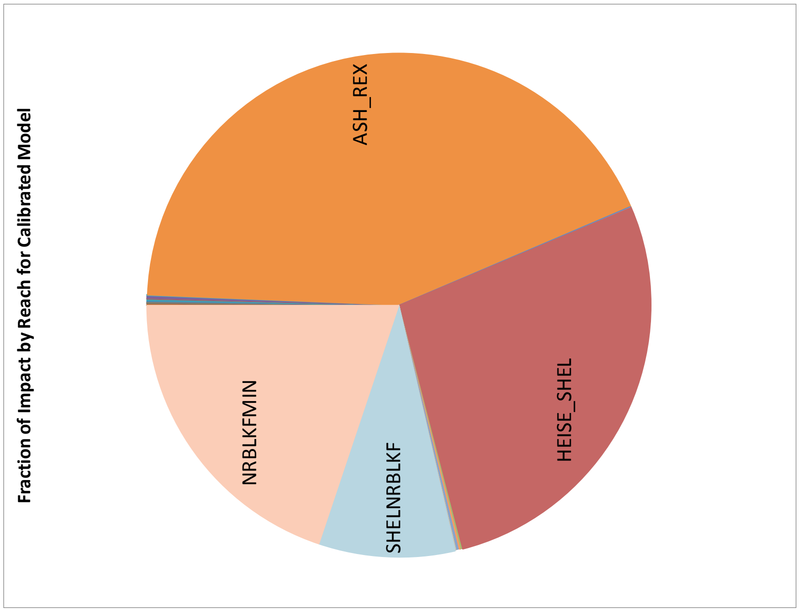
Impact of Water District 100 on Clear Lakes Spring using calibration run E120116A008.

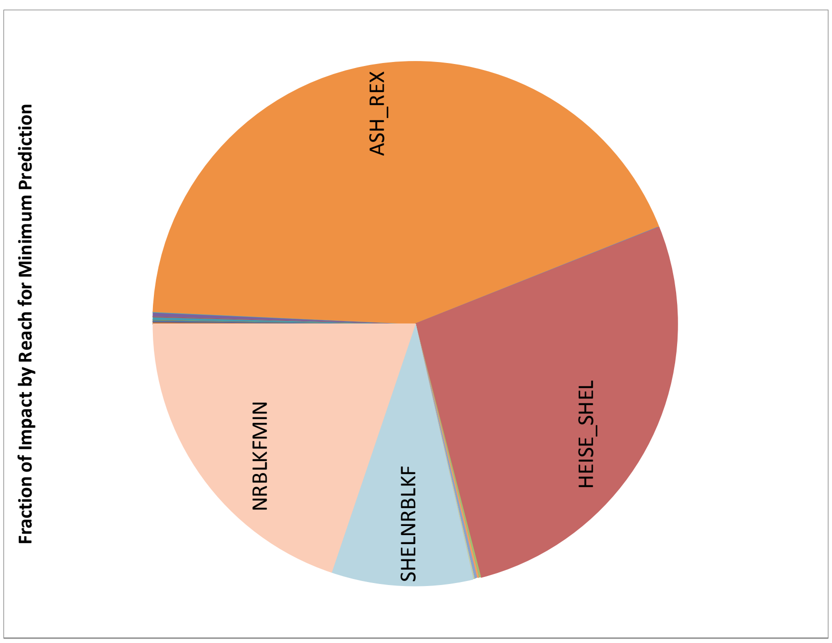


Impact of Water District 100 on near Blackfoot-Minidoka using calibration run E120116A008.

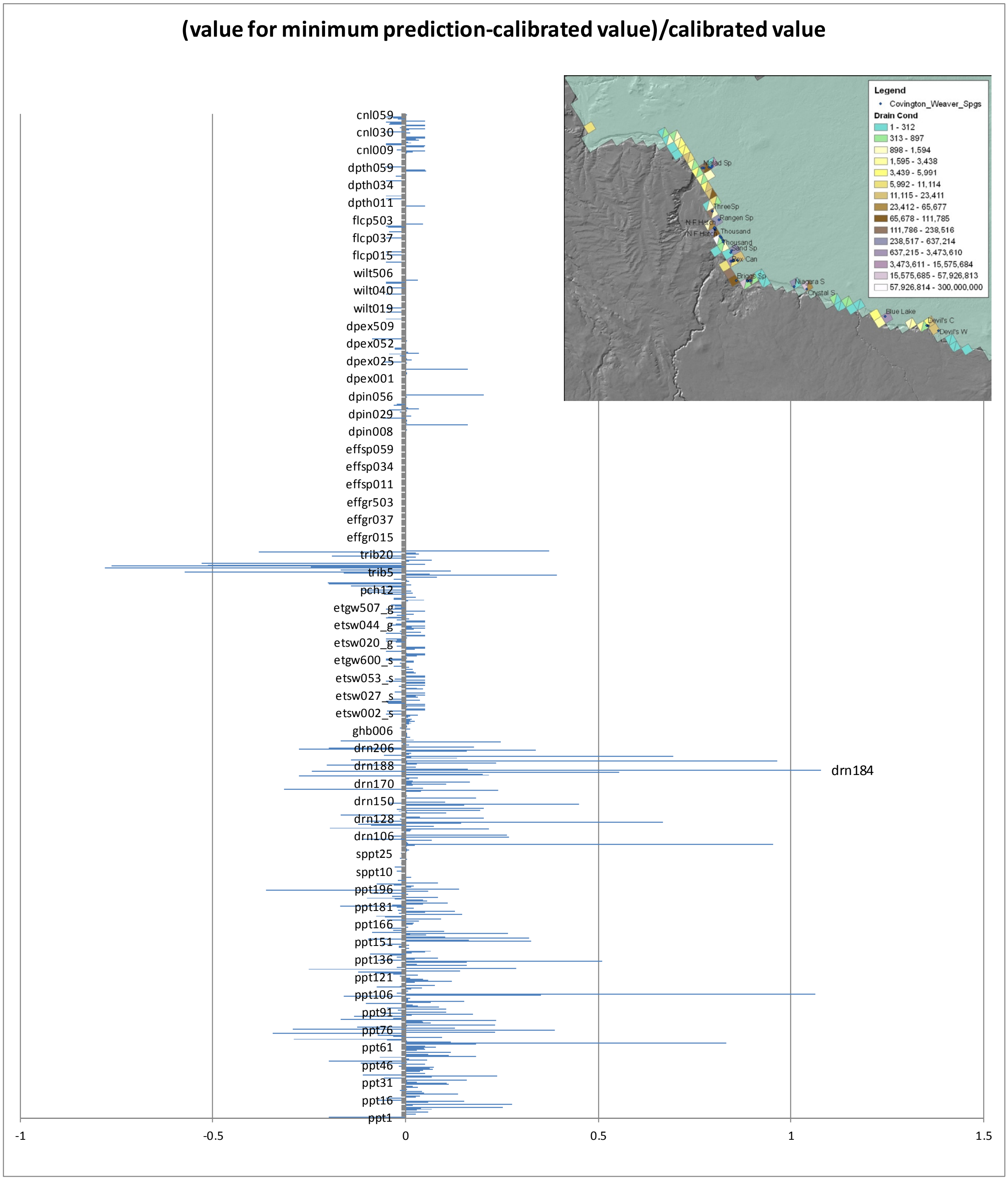


Impact of Water District 100 on near Blackfoot-Minidoka using calibration run E120116A008.

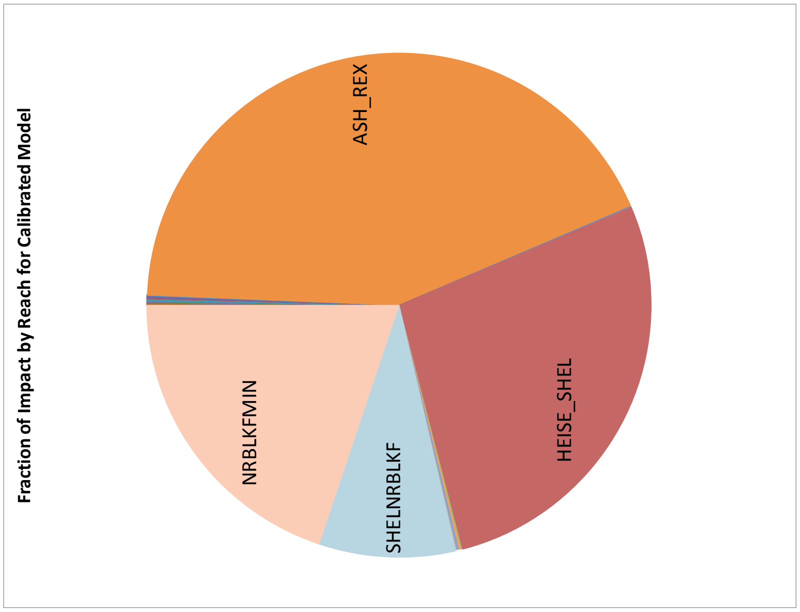


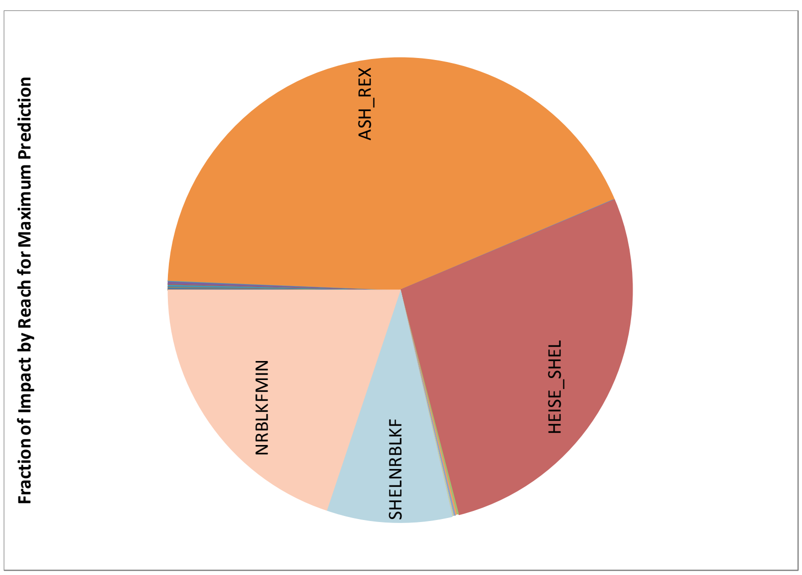


Impact of Water District 100 on near Blackfoot-Minidoka using calibration run E120116A008.

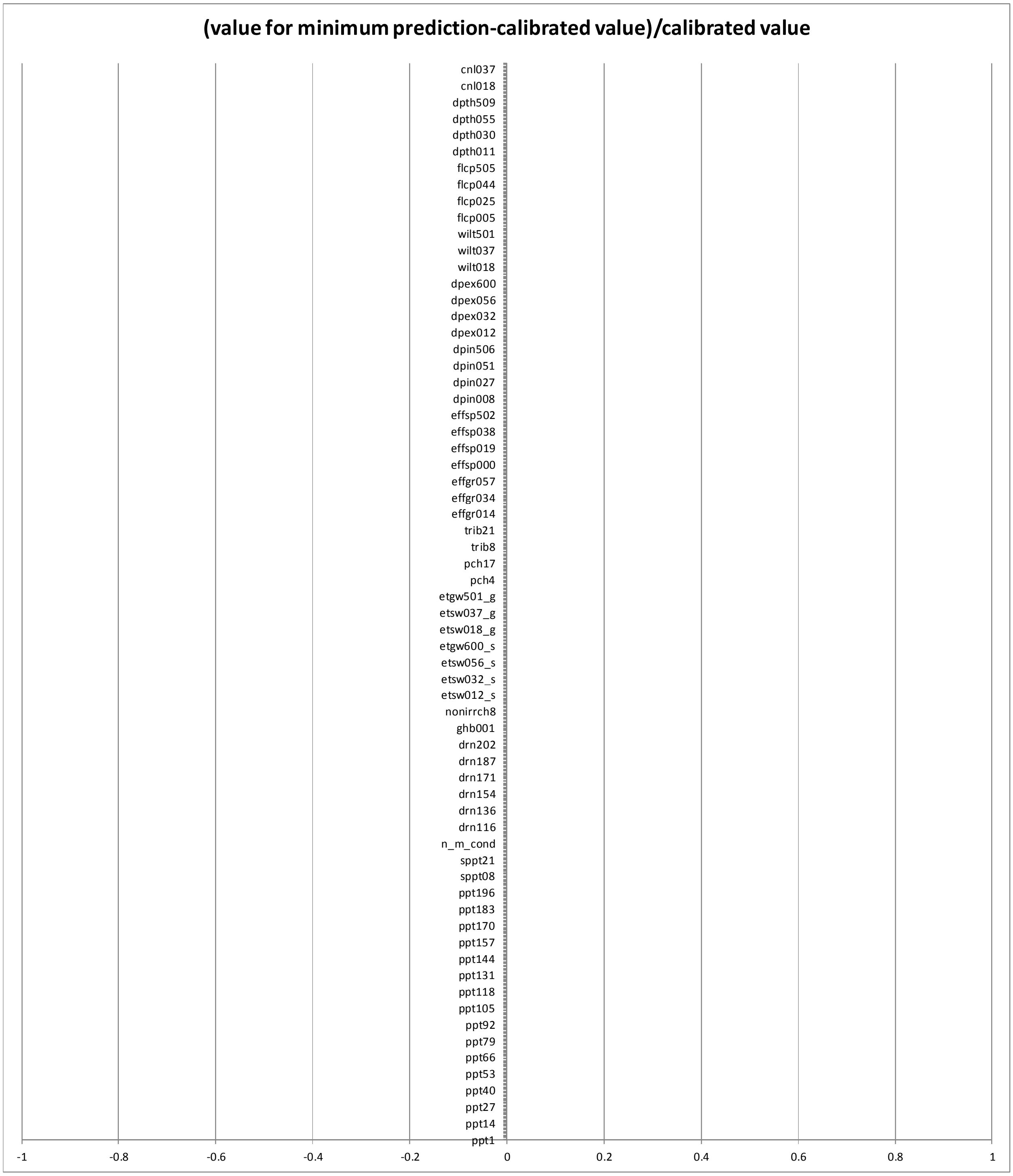


Impact of Water District 100 on near Blackfoot-Minidoka using calibration run E120116A008.

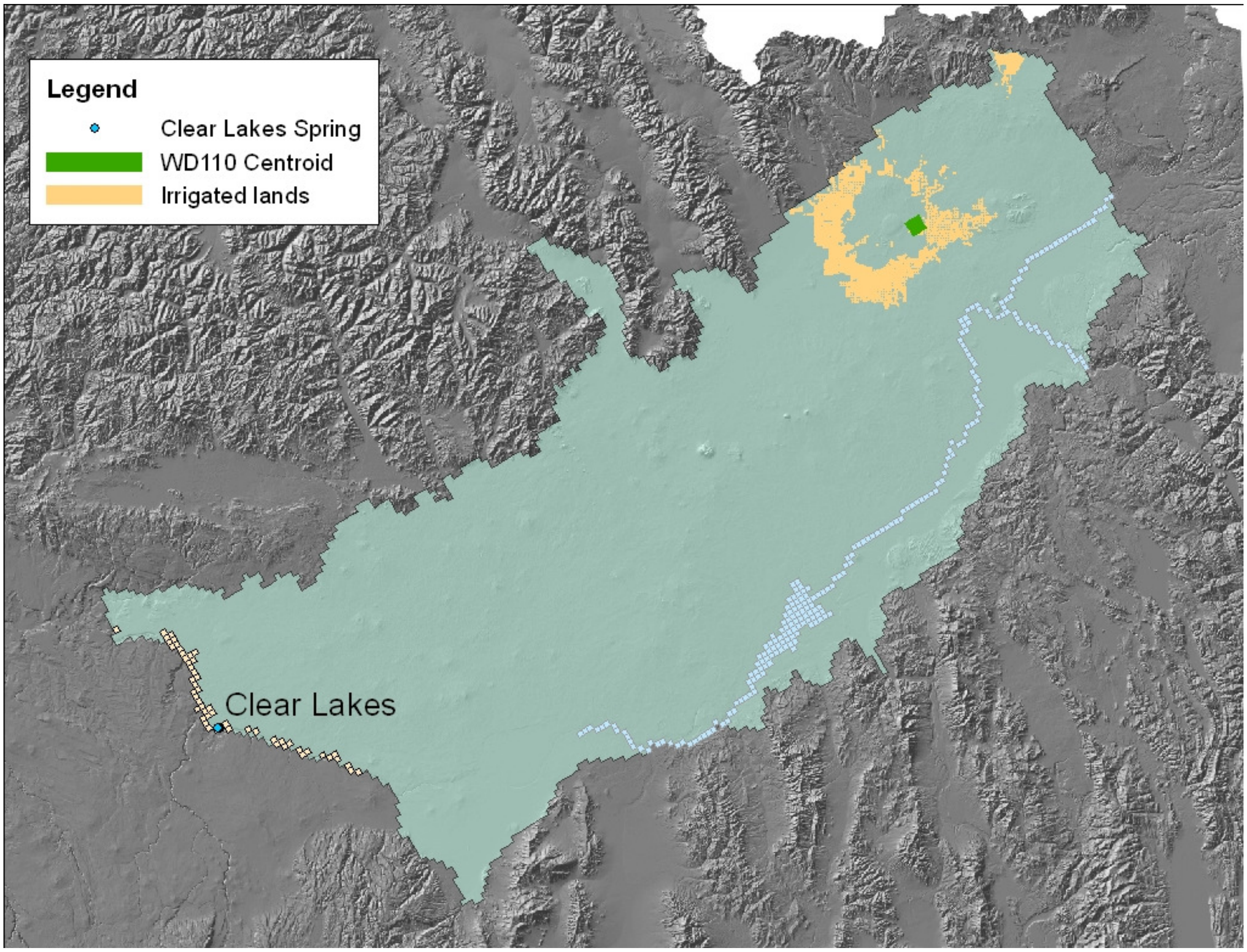




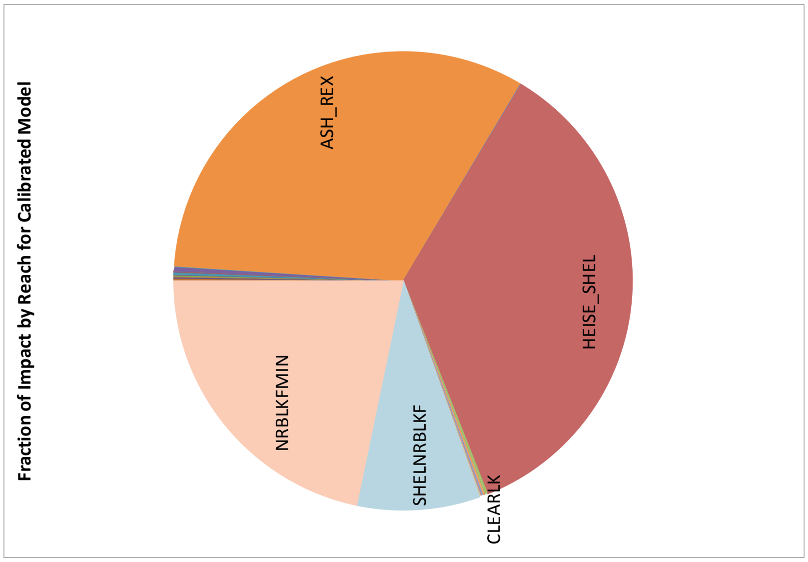
Impact of Water District 100 on near Blackfoot-Minidoka using calibration run E120116A008.

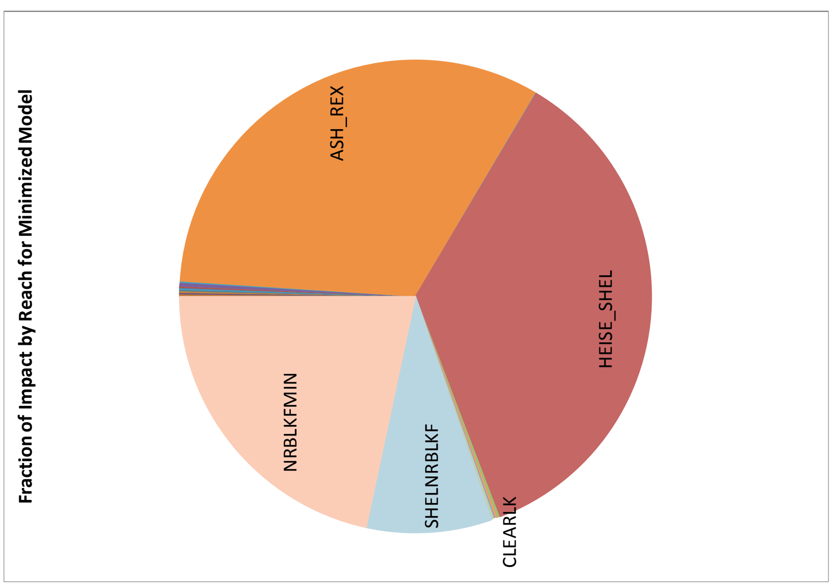


Impact of Water District 110 on Clear Lakes Spring using calibration run E110712A001.

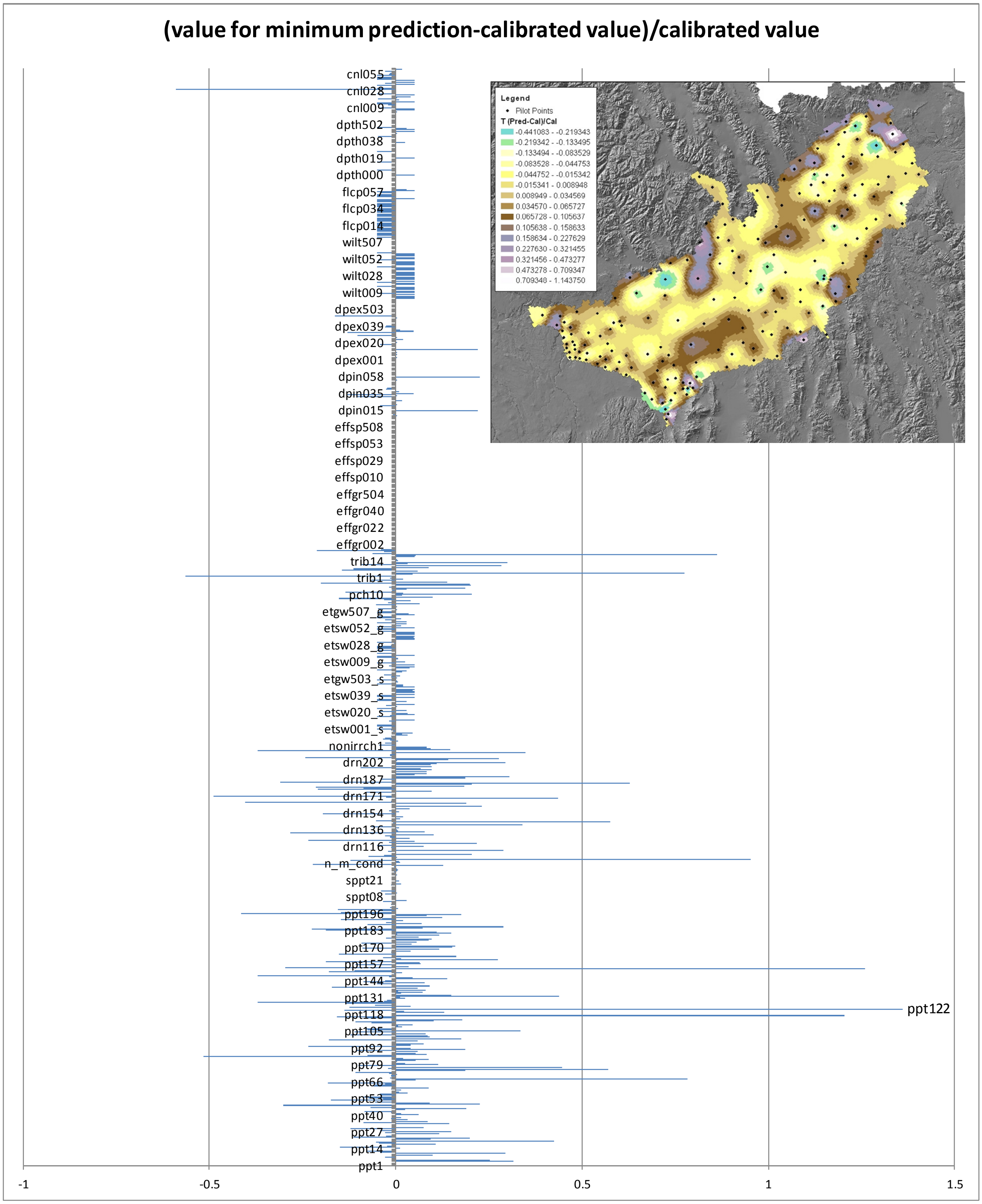


Impact of Water District 110 on Clear Lakes Spring using calibration run E110712A001.

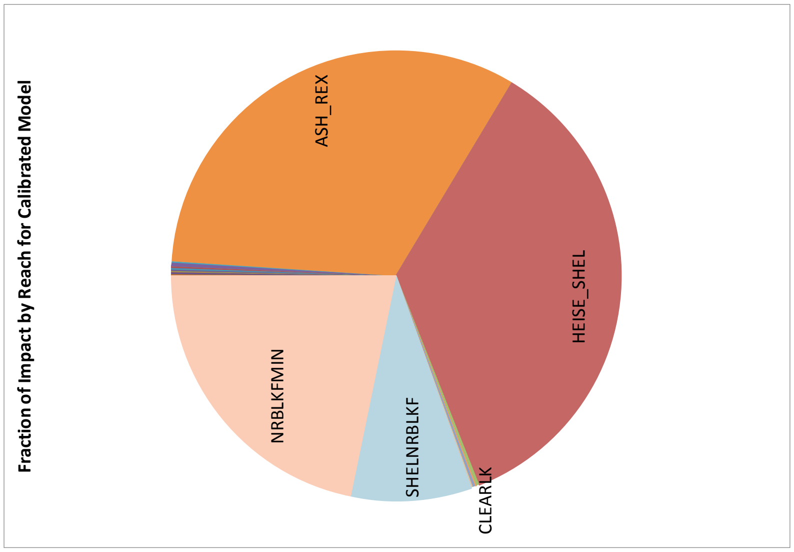


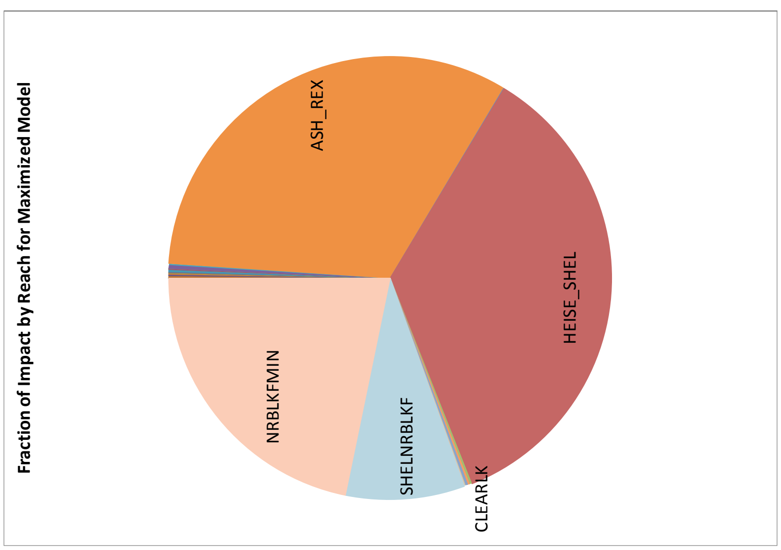


Impact of Water District 110 on Clear Lakes Spring using calibration run E110712A001.

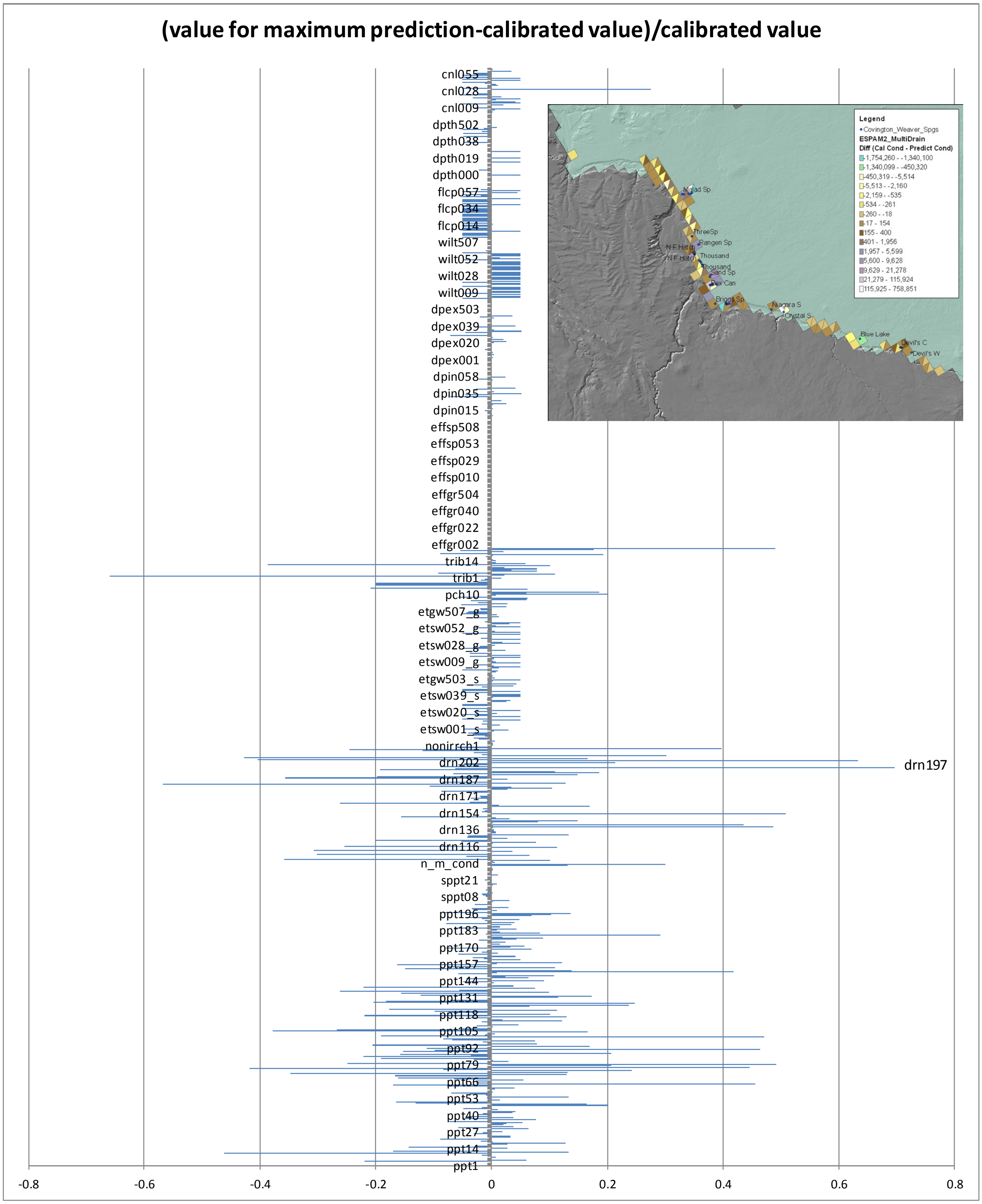


Impact of Water District 110 on Clear Lakes Spring using calibration run E110712A001.

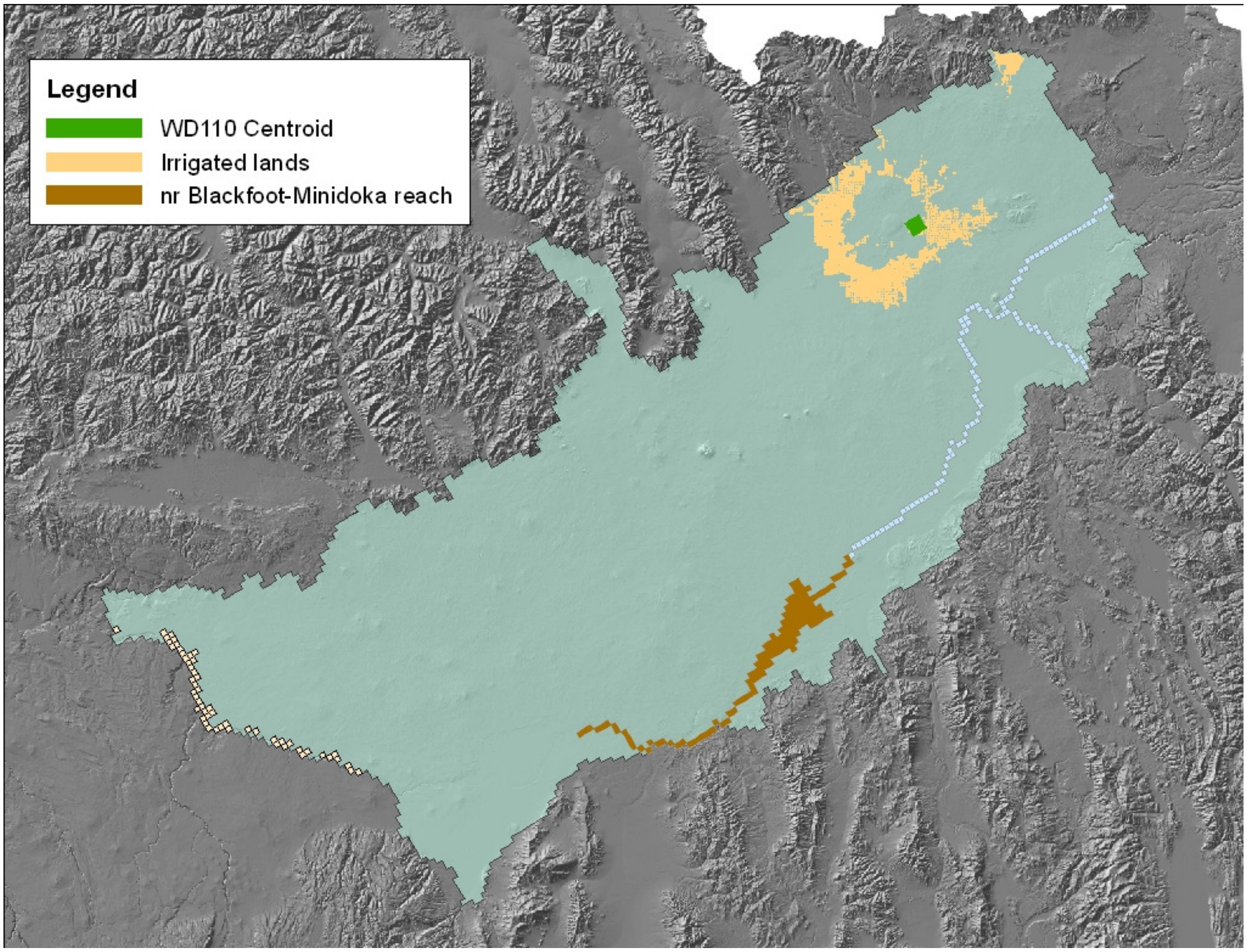




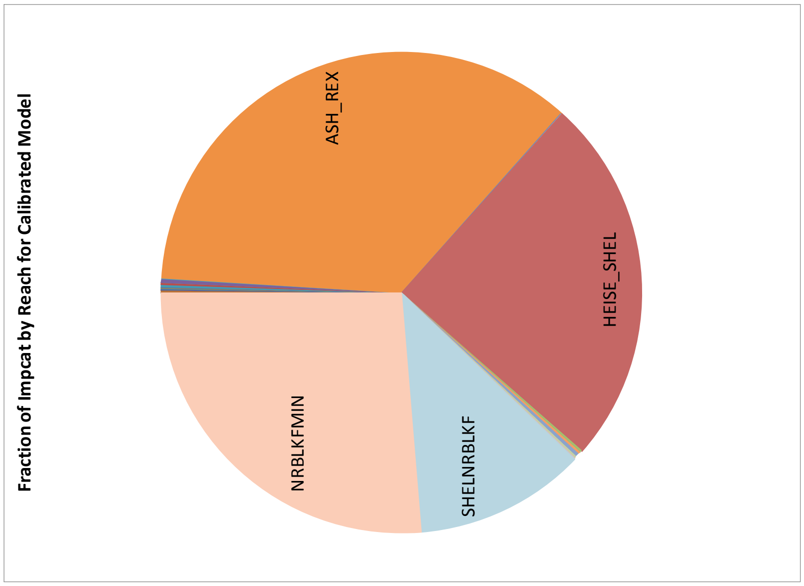
Impact of Water District 110 on Clear Lakes Spring using calibration run E110712A001.

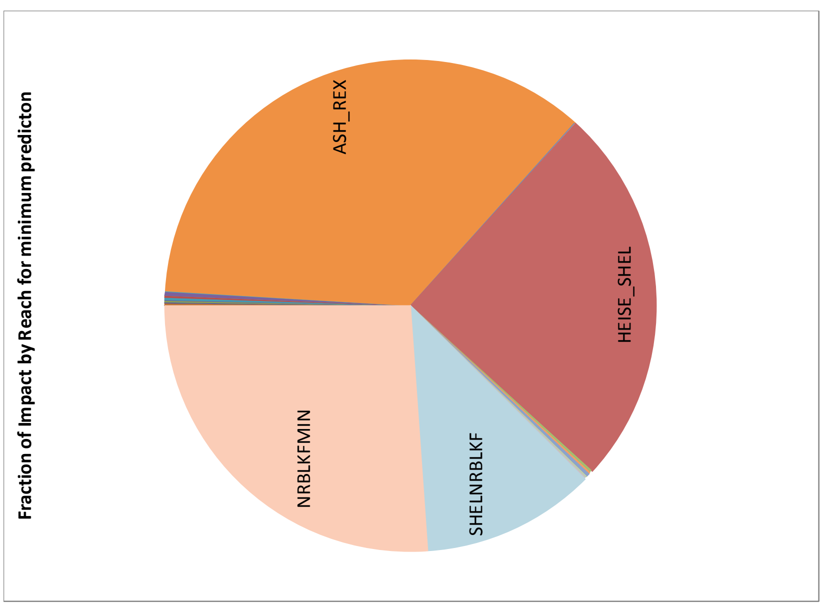


Impact of Water District 110 on near Blackfoot-Minidoka using calibration run E120116A008.

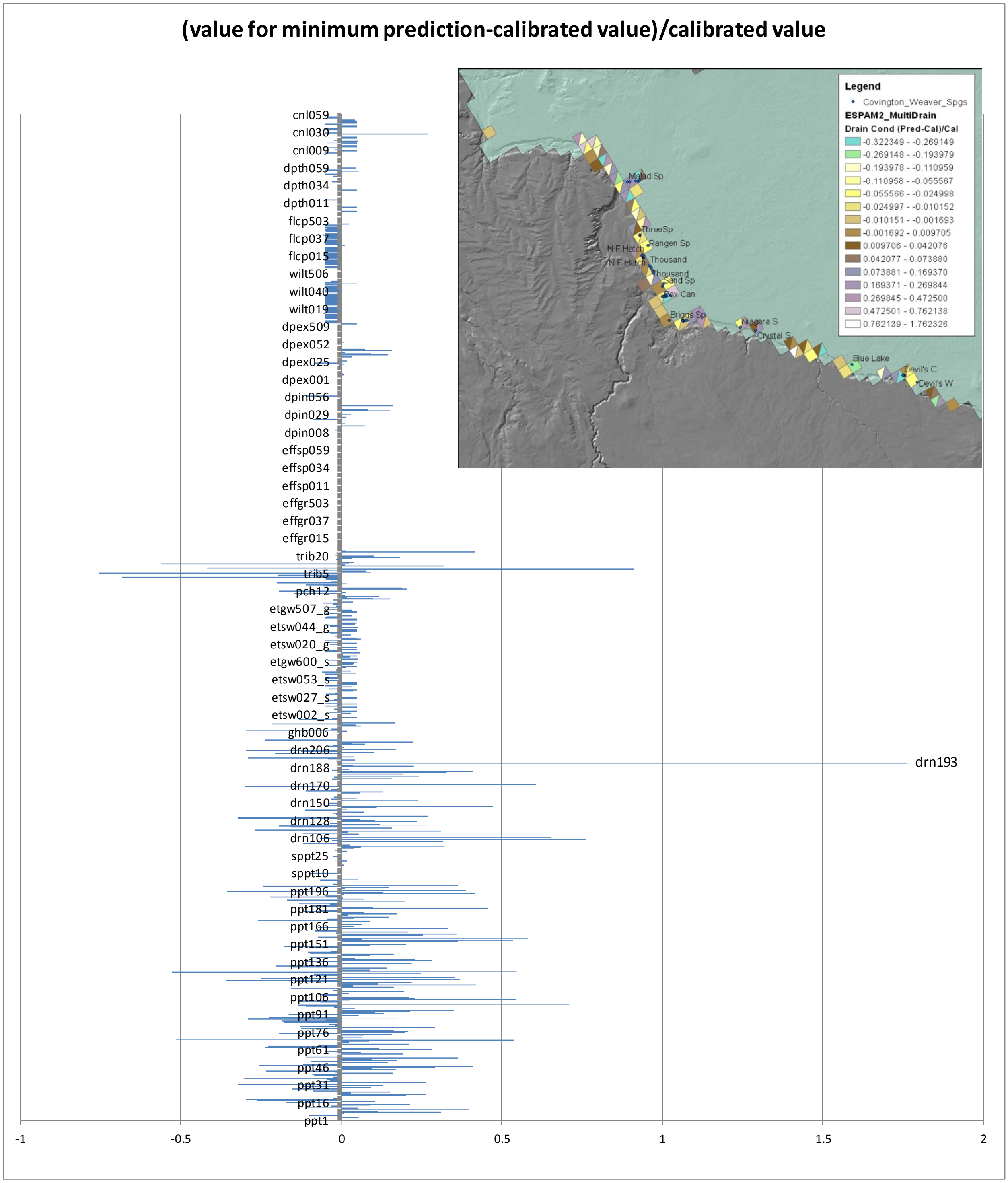


Impact of Water District 110 on near Blackfoot-Minidoka using calibration run E120116A008.

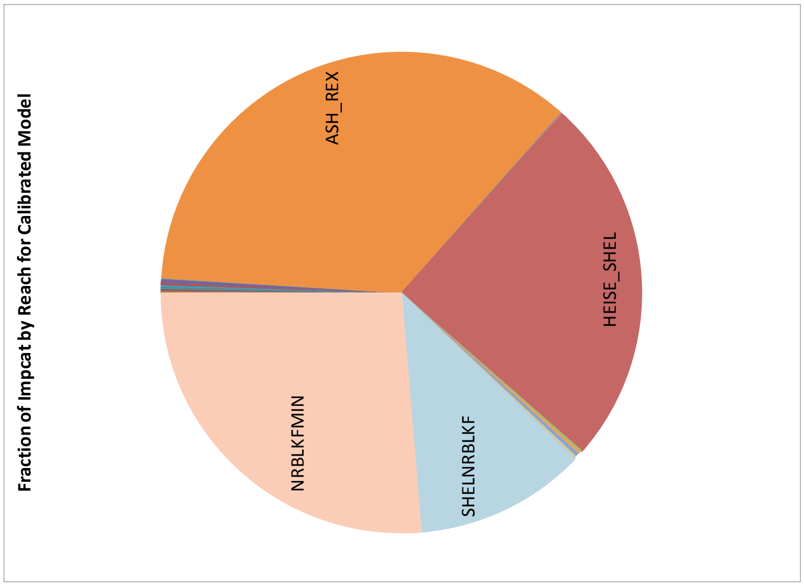


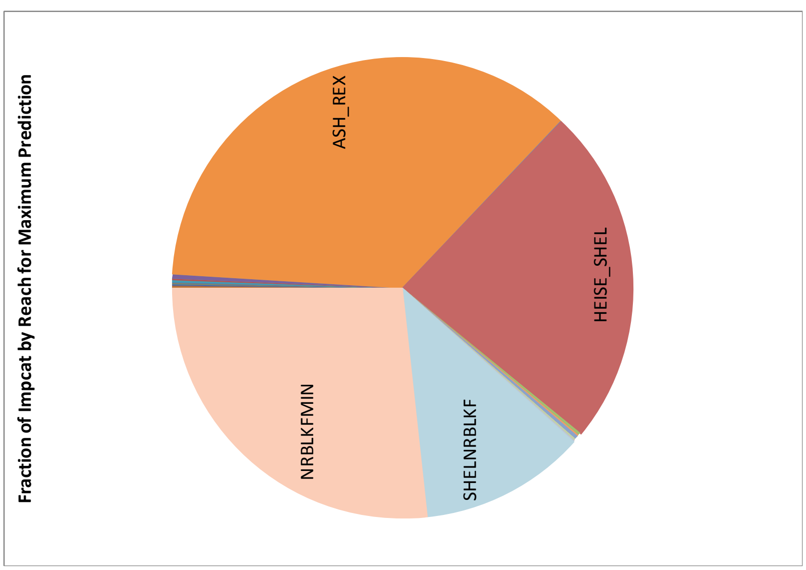


Impact of Water District 110 on near Blackfoot-Minidoka using calibration run E120116A008.

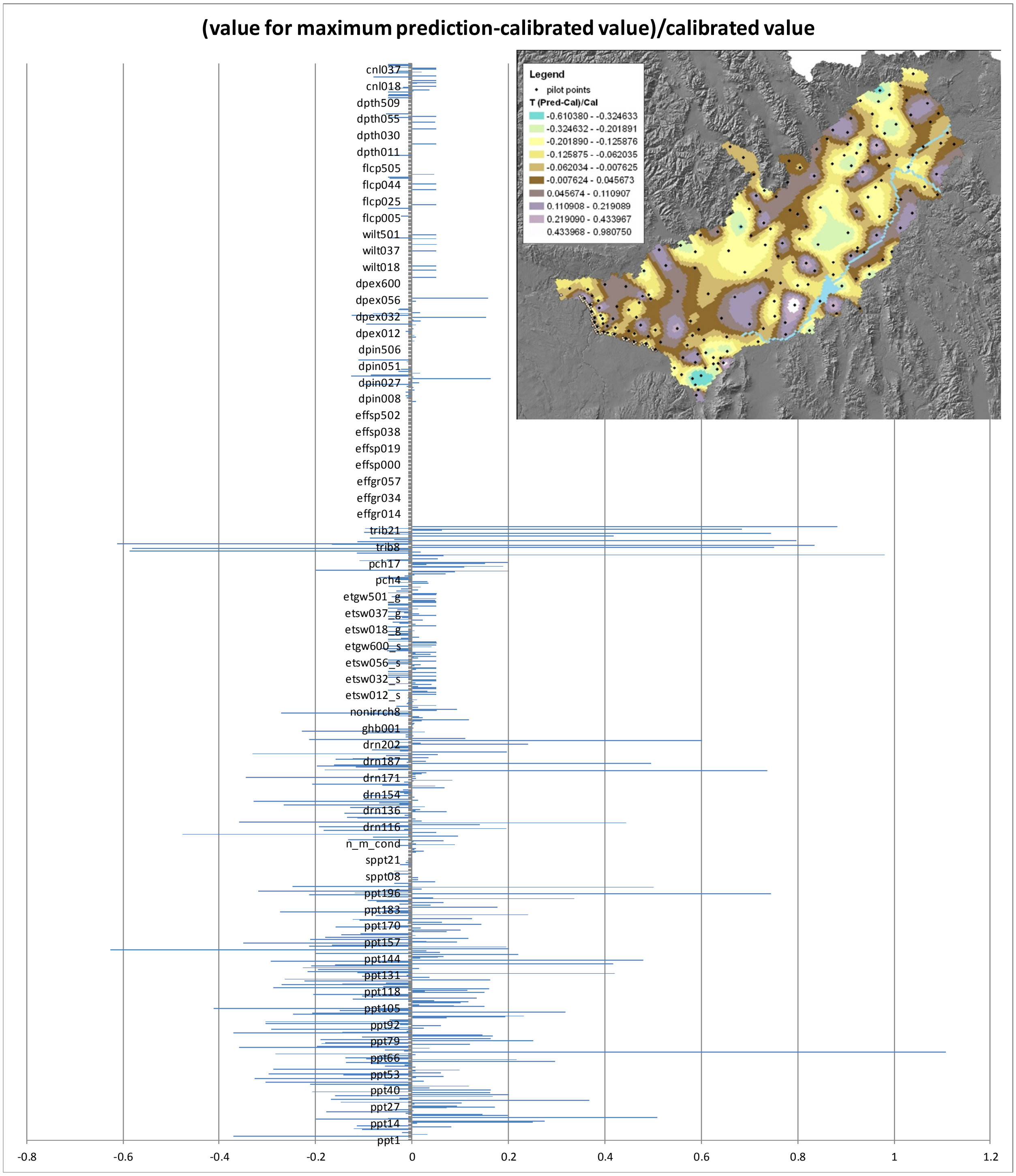


Impact of Water District 110 on near Blackfoot-Minidoka using calibration run E120116A008.

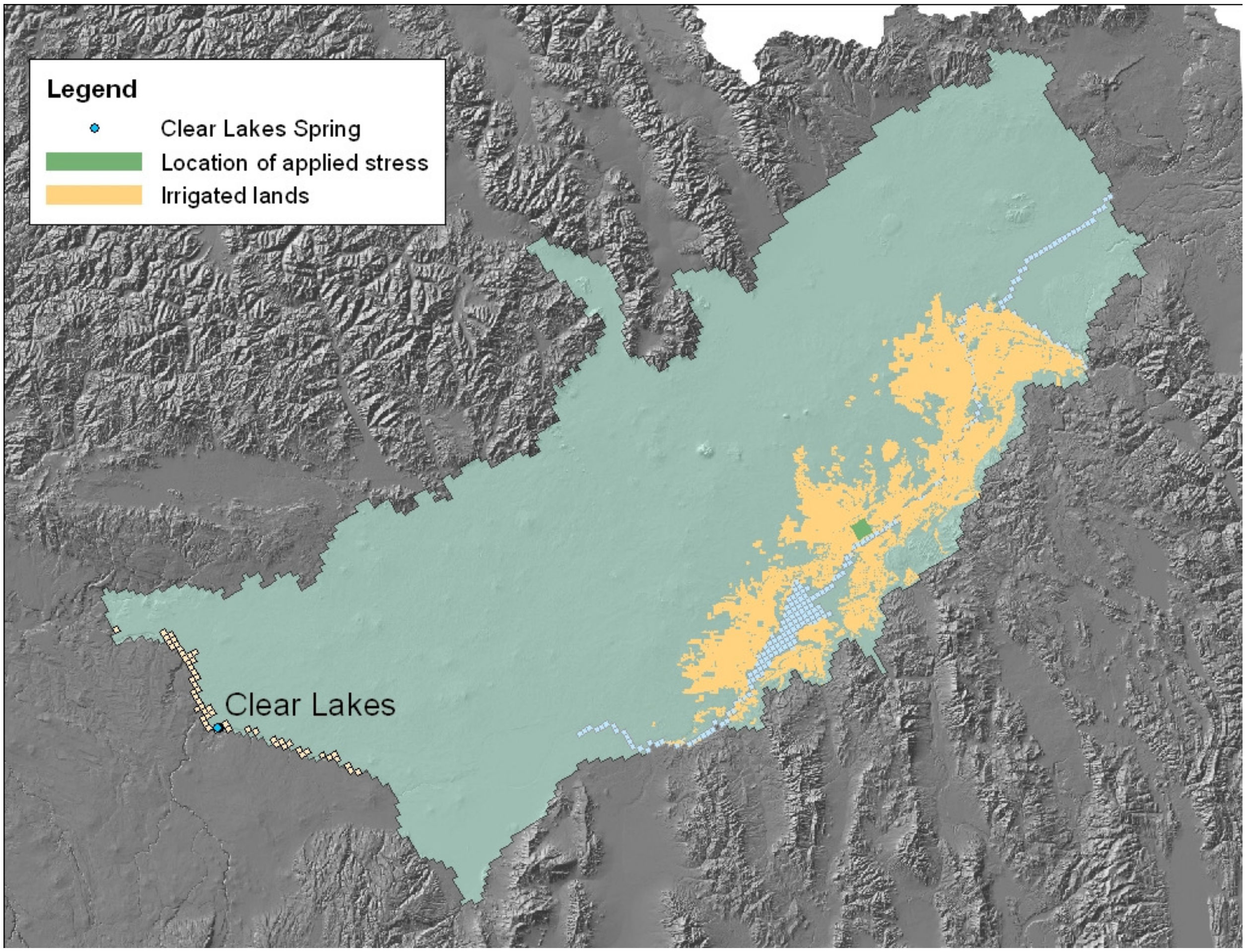




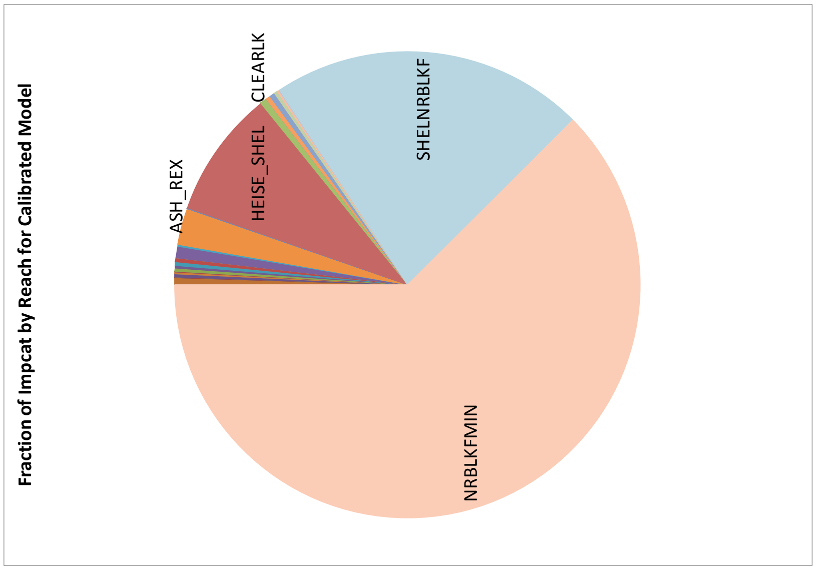
Impact of Water District 110 on near Blackfoot-Minidoka using calibration run E120116A008.

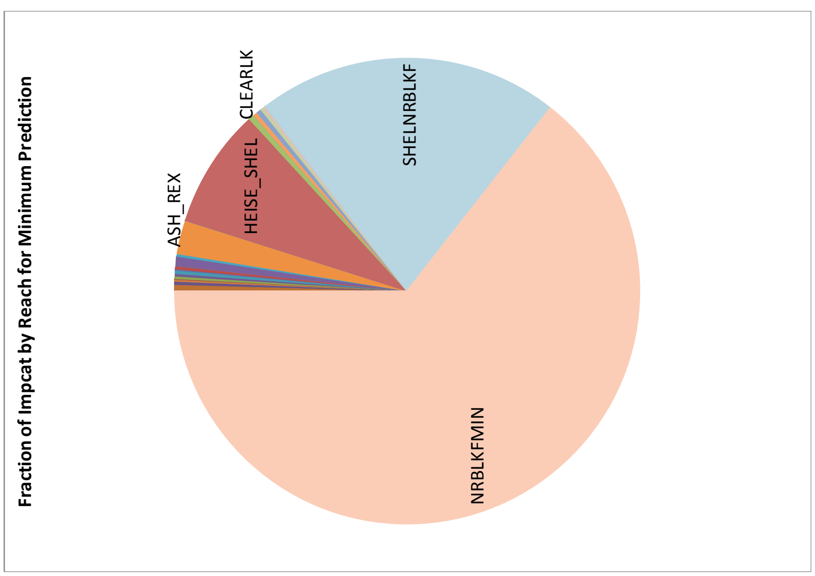


Impact of Water District 120 on Clear Lakes Spring using calibration run E110712A001.

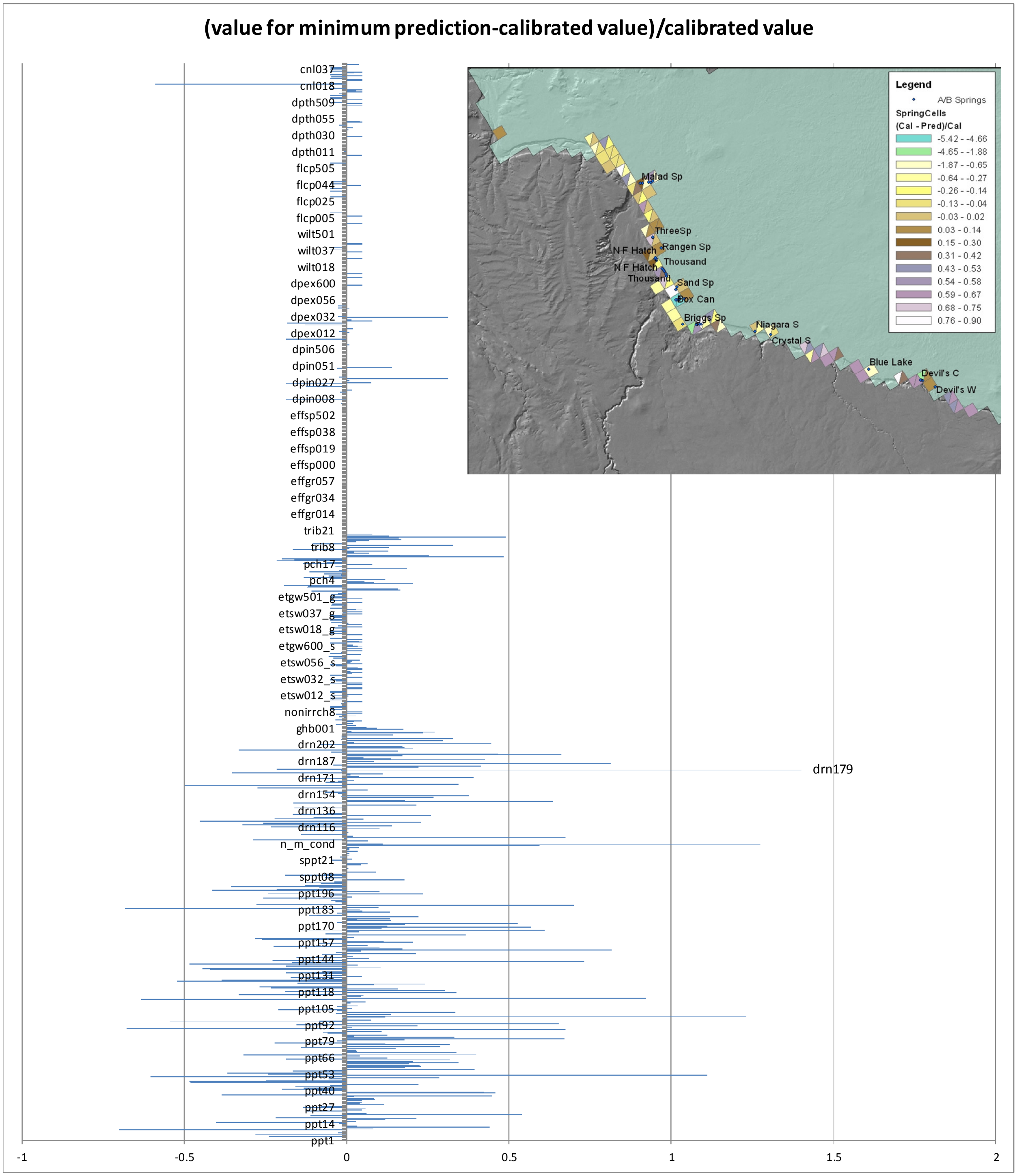


Impact of Water District 120 on Clear Lakes Spring using calibration run E110712A001.

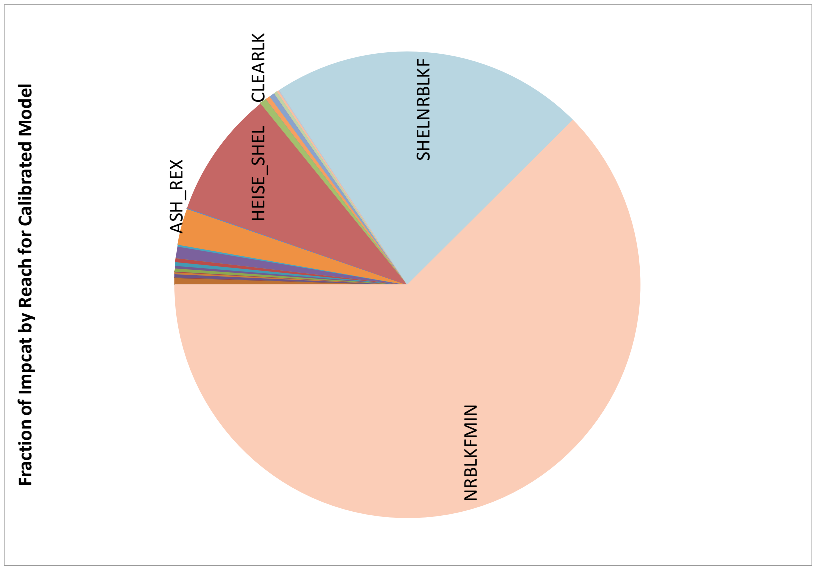


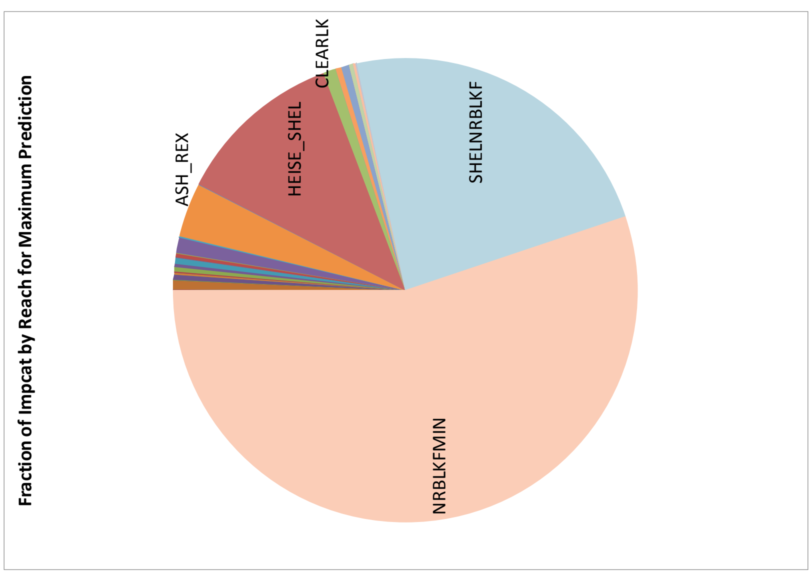


Impact of Water District 120 on Clear Lakes Spring using calibration run E110712A001.

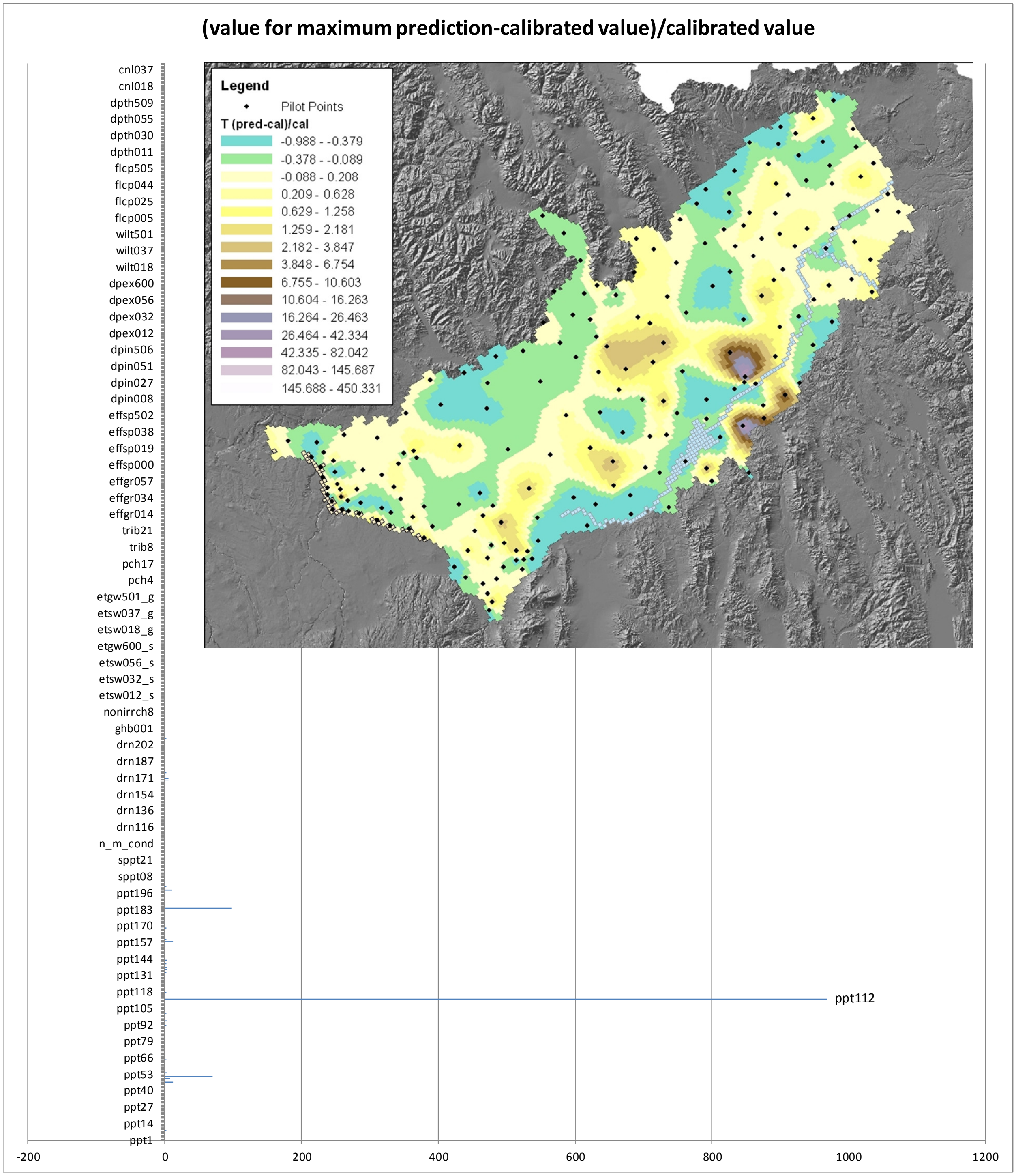


Impact of Water District 120 on Clear Lakes Spring using calibration run E110712A001.

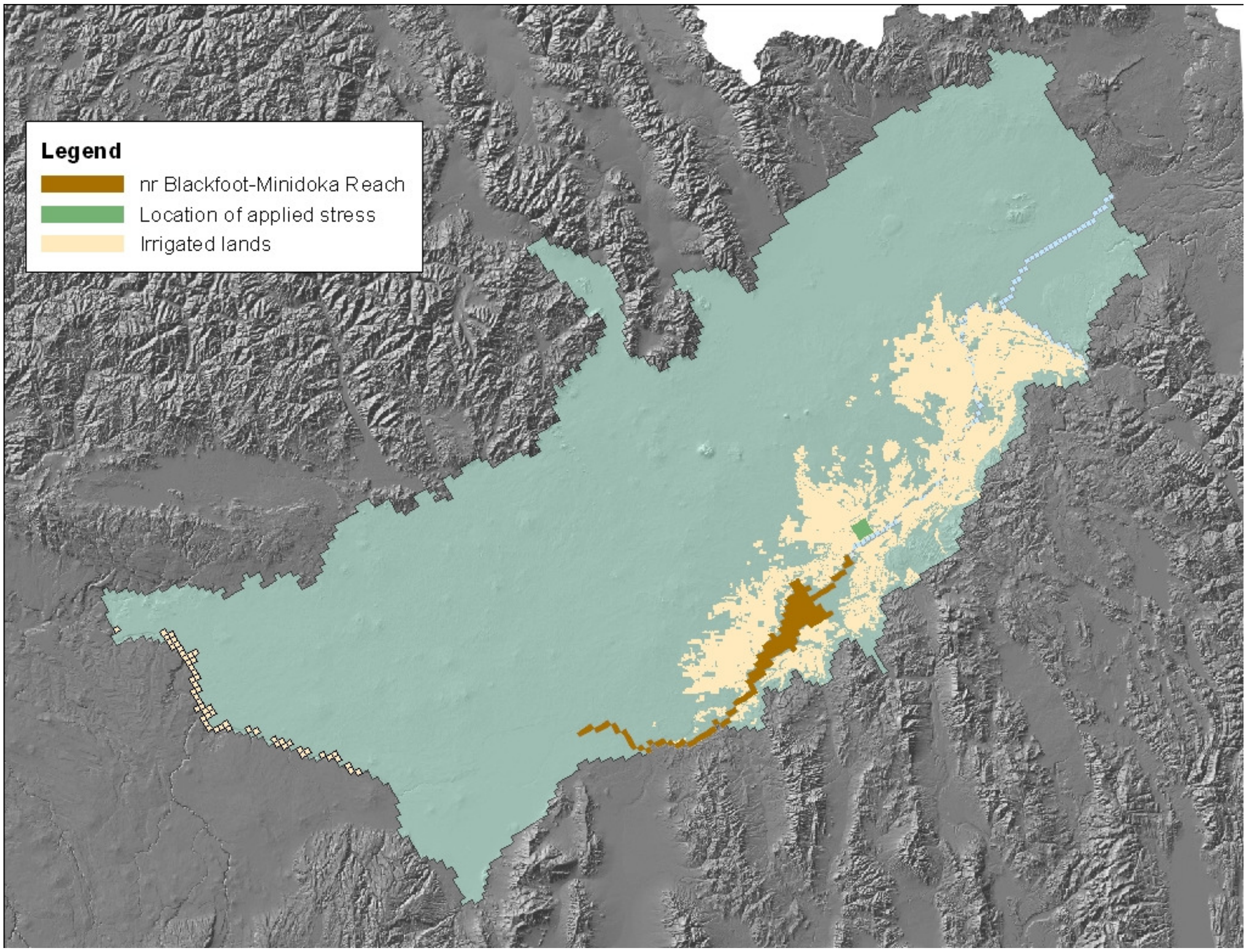




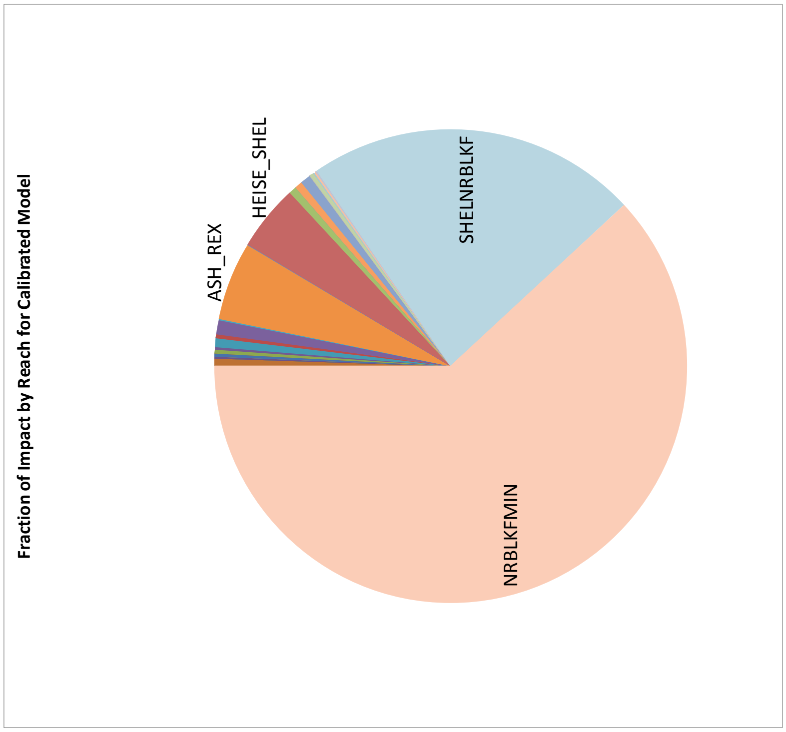
Impact of Water District 120 on Clear Lakes Spring using calibration run E110712A001.

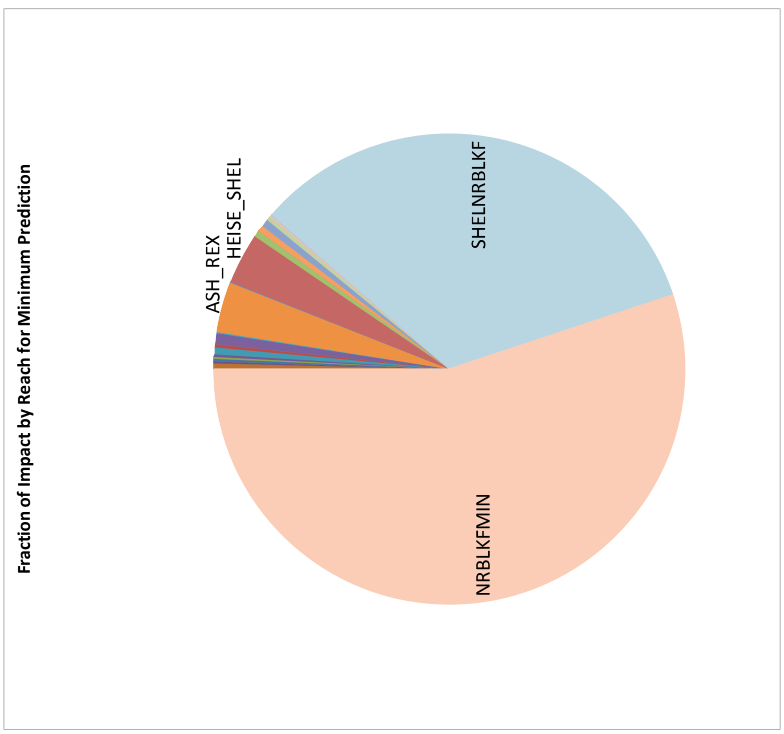


Impact of Water District 120 on near Blackfoot-Minidoka using calibration run E120116A008.

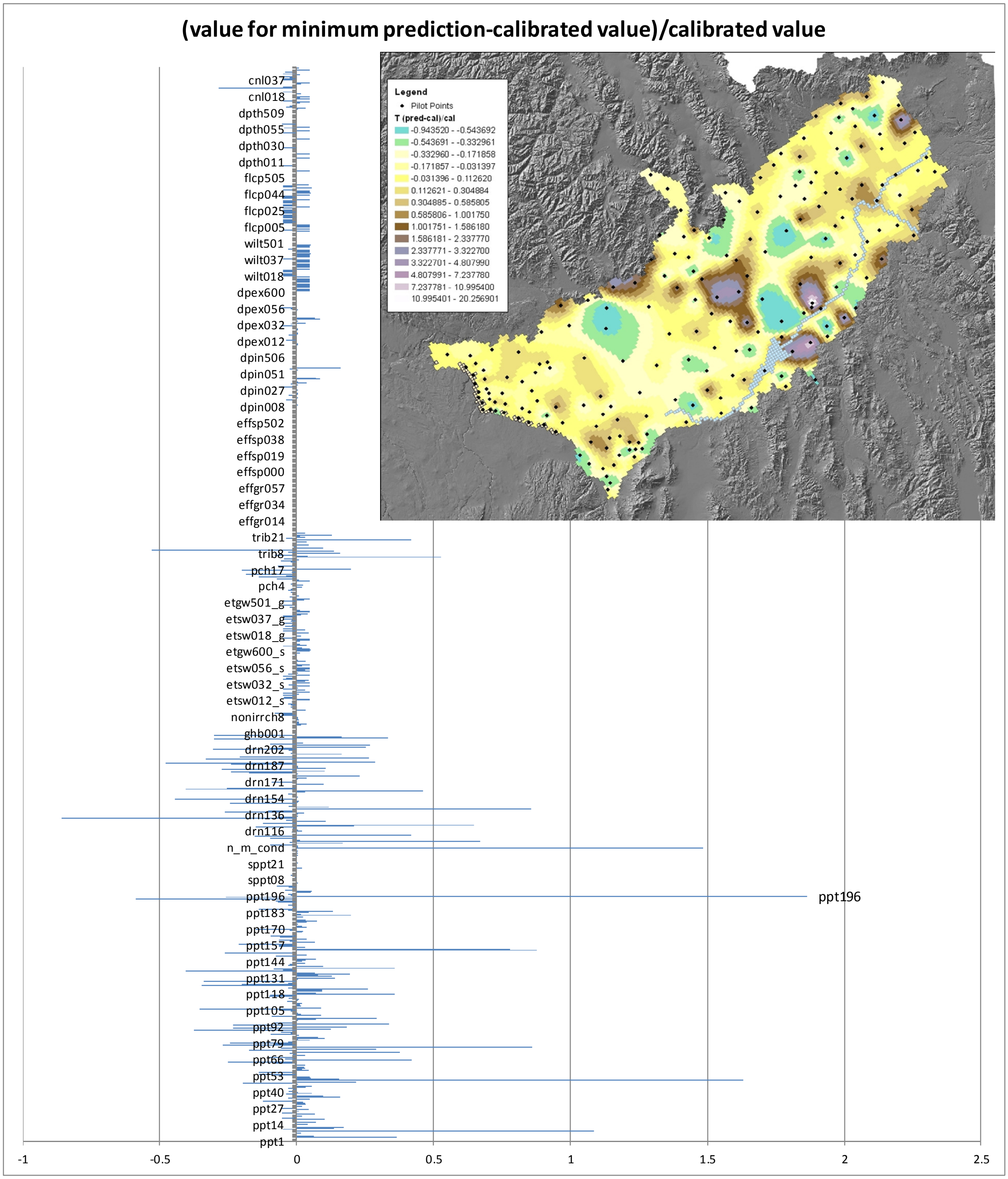


Impact of Water District 120 on near Blackfoot-Minidoka using calibration run E120116A008.

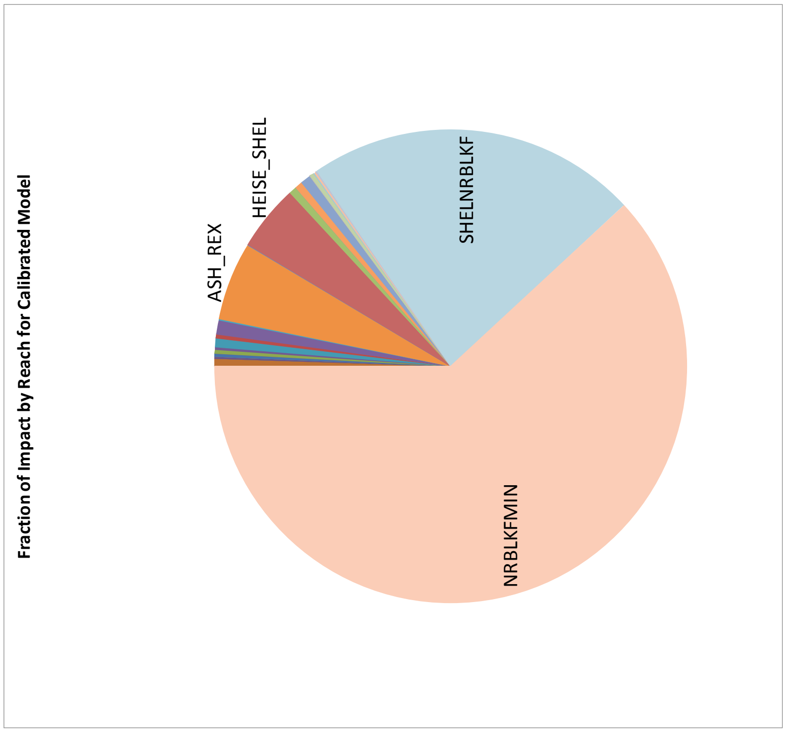


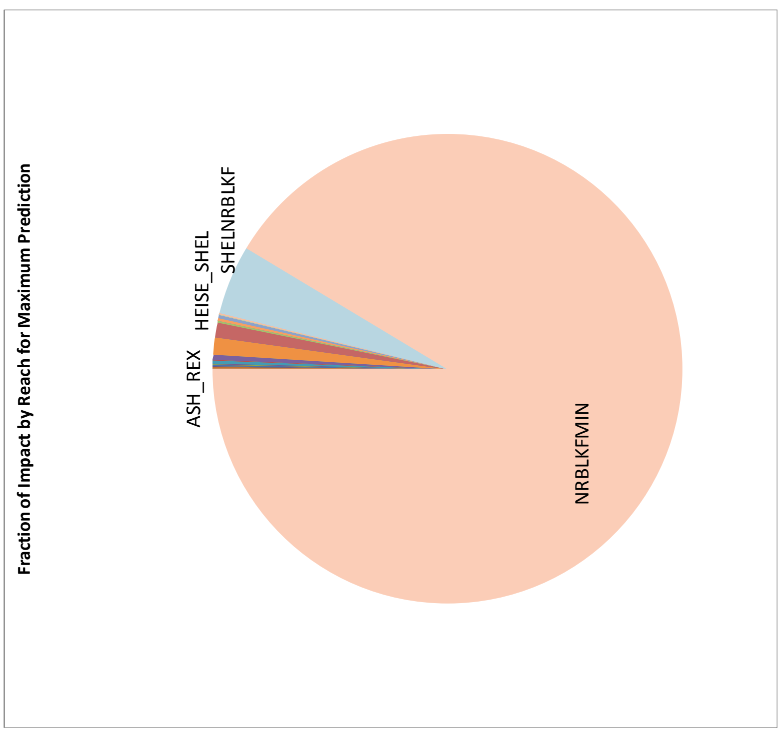


Impact of Water District 120 on near Blackfoot-Minidoka using calibration run E120116A008.

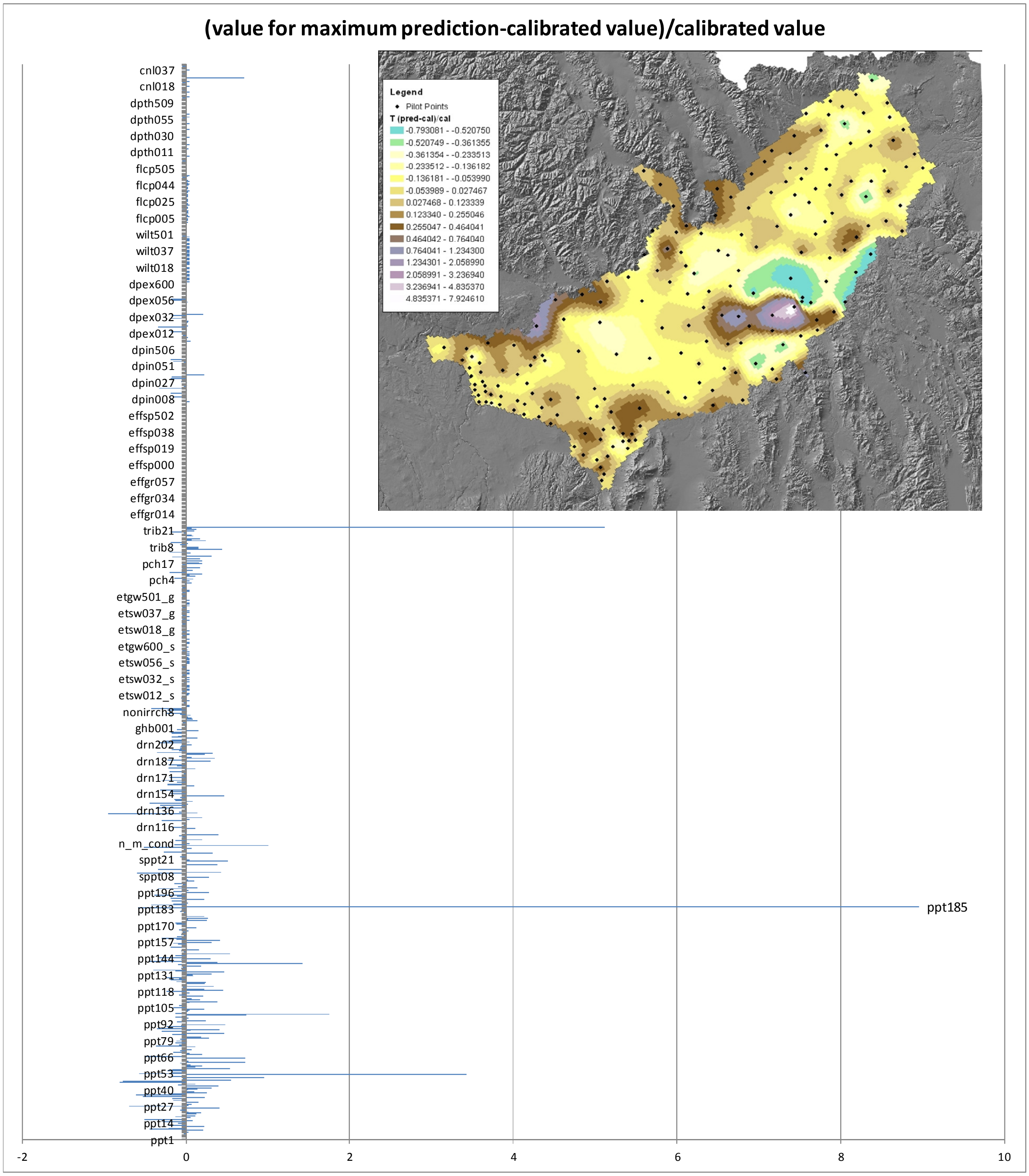


Impact of Water District 120 on near Blackfoot-Minidoka using calibration run E120116A008.

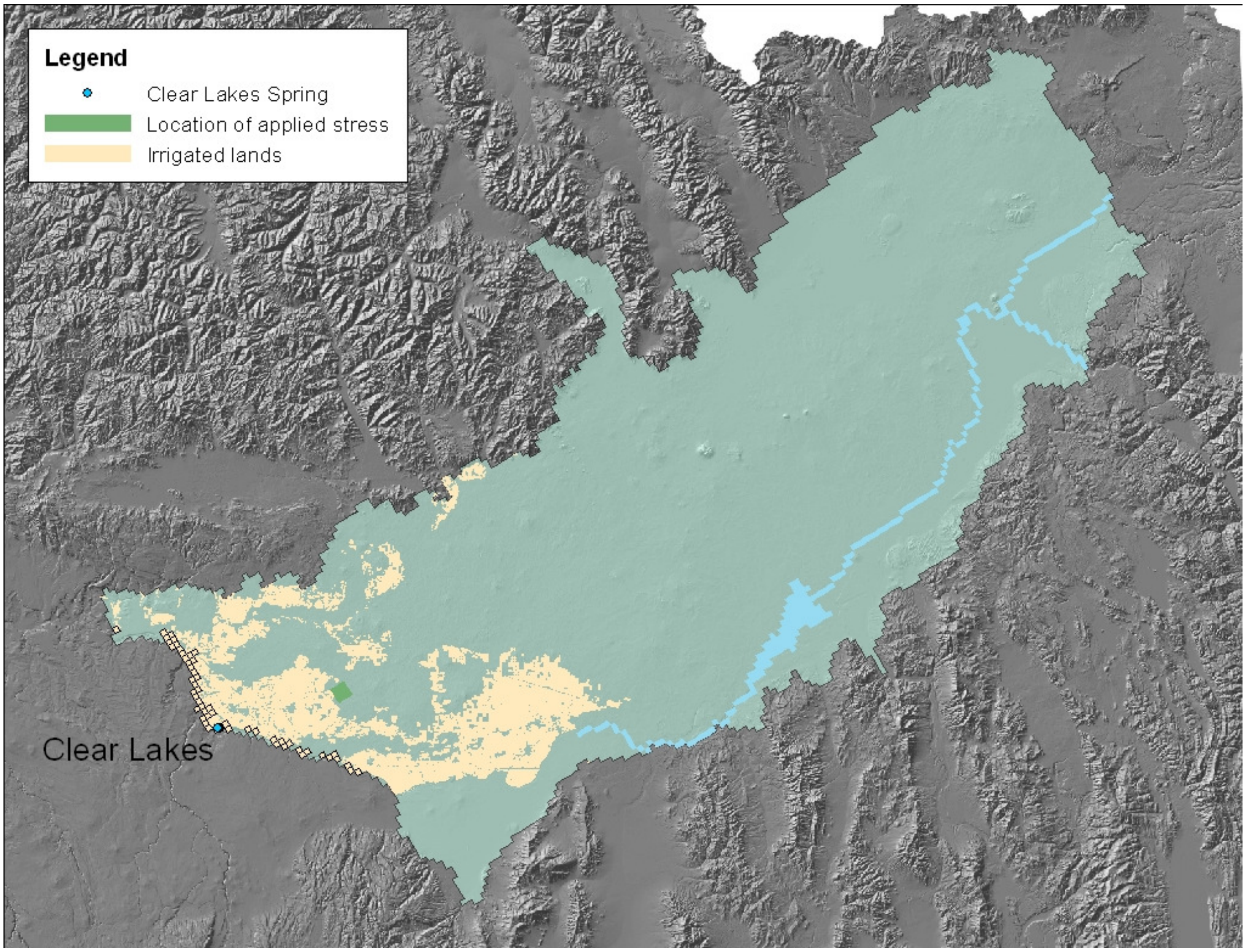




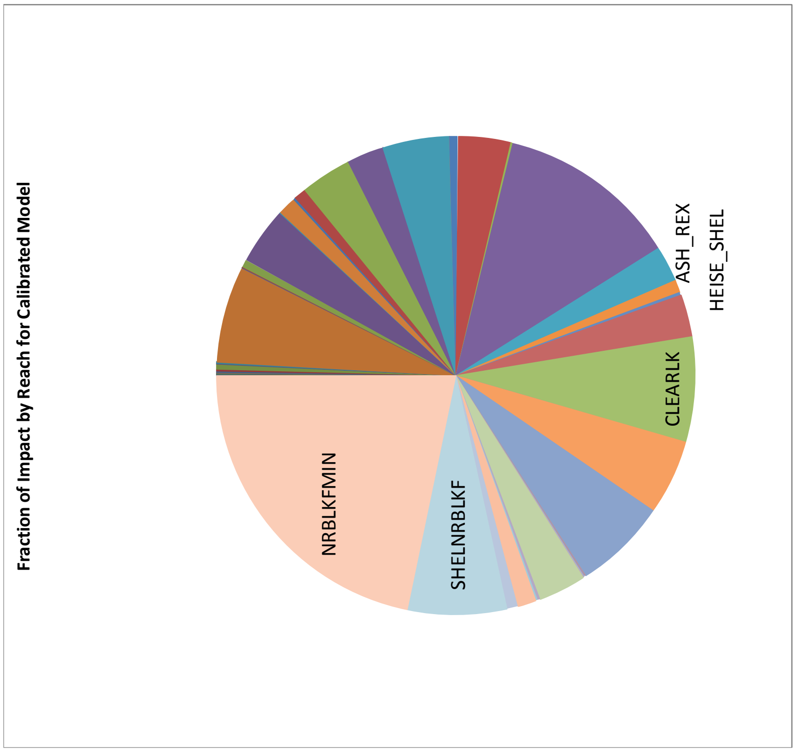
Impact of Water District 120 on near Blackfoot-Minidoka using calibration run E120116A008.

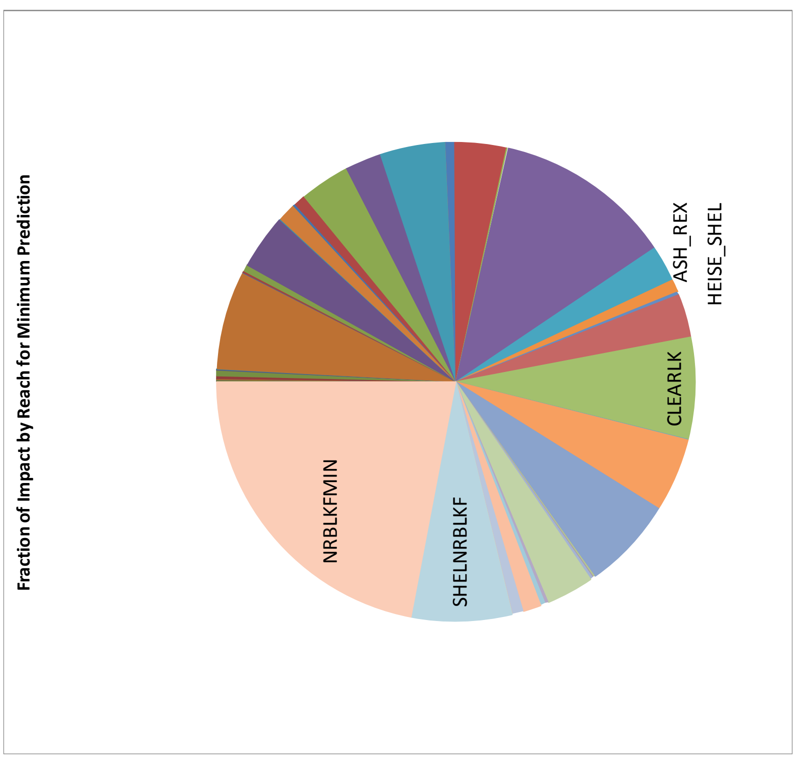


Impact of Water District 130 on Clear Lakes Spring using calibration run E110712A001.

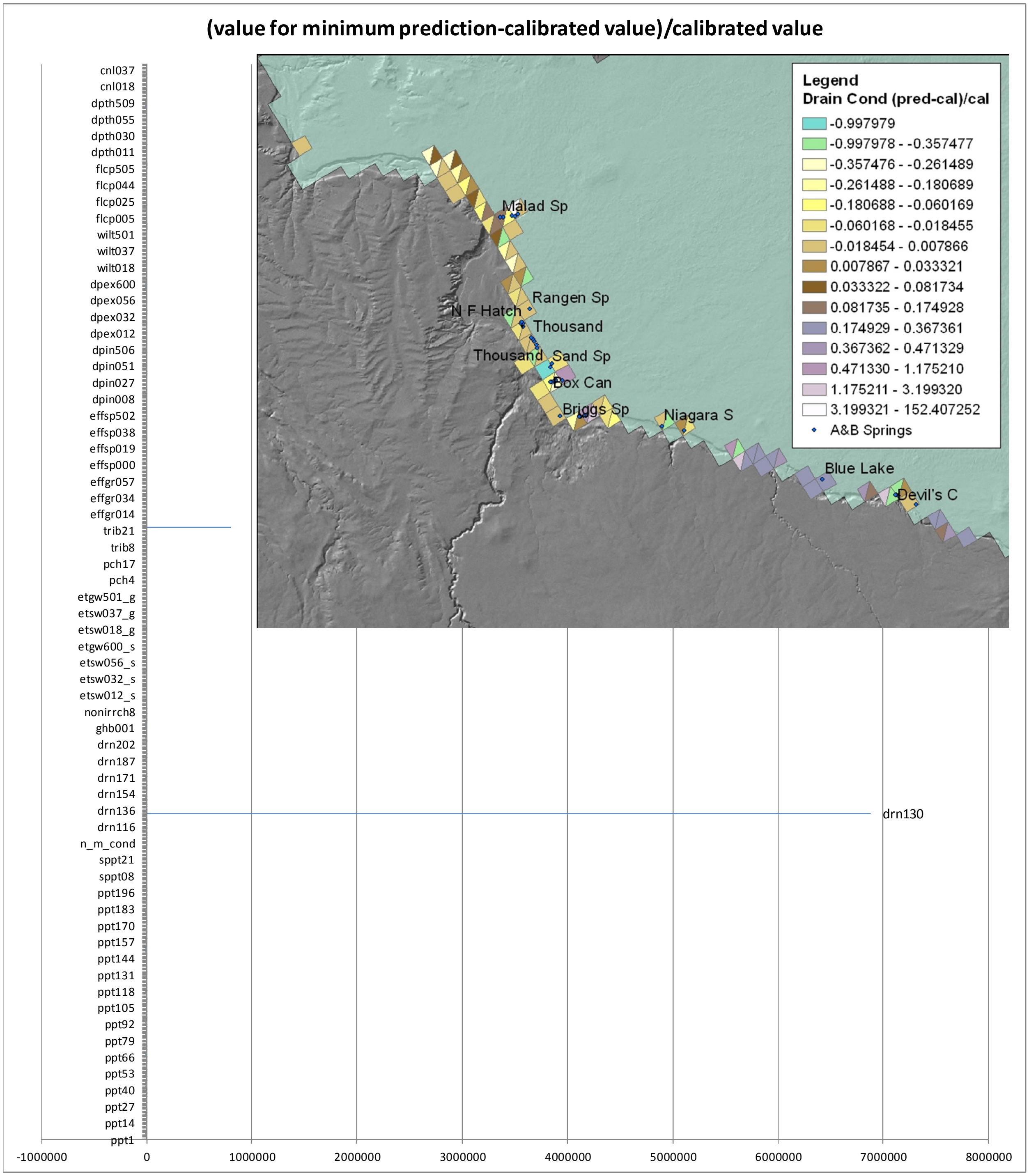


Impact of Water District 130 on Clear Lakes Spring using calibration run E110712A001.

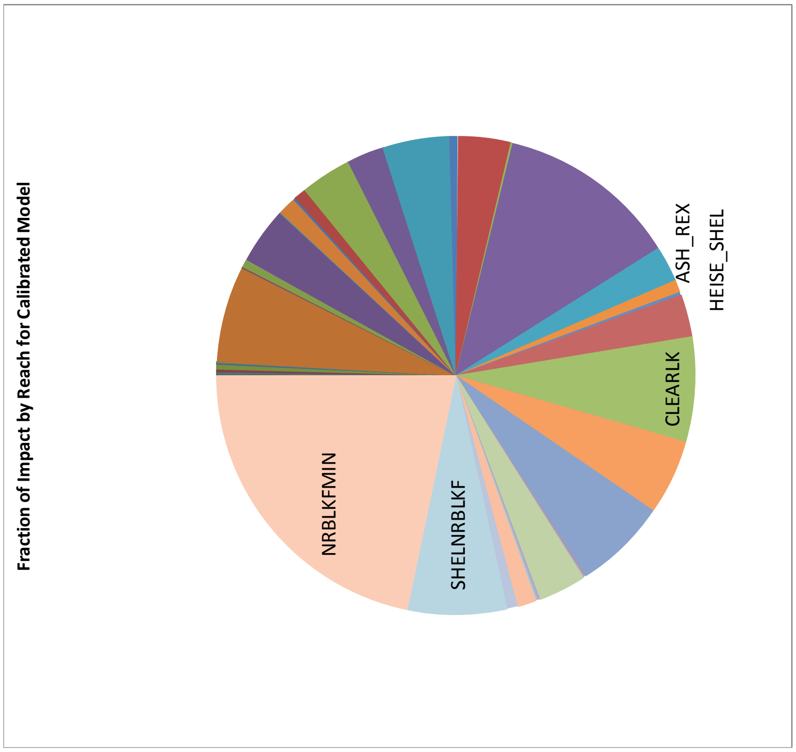


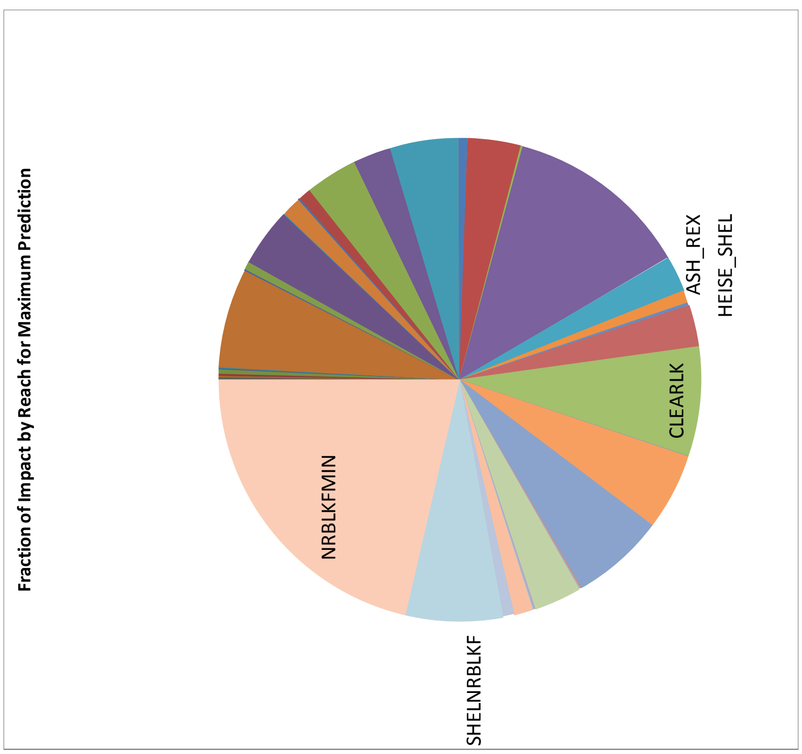


Impact of Water District 130 on Clear Lakes Spring using calibration run E110712A001.

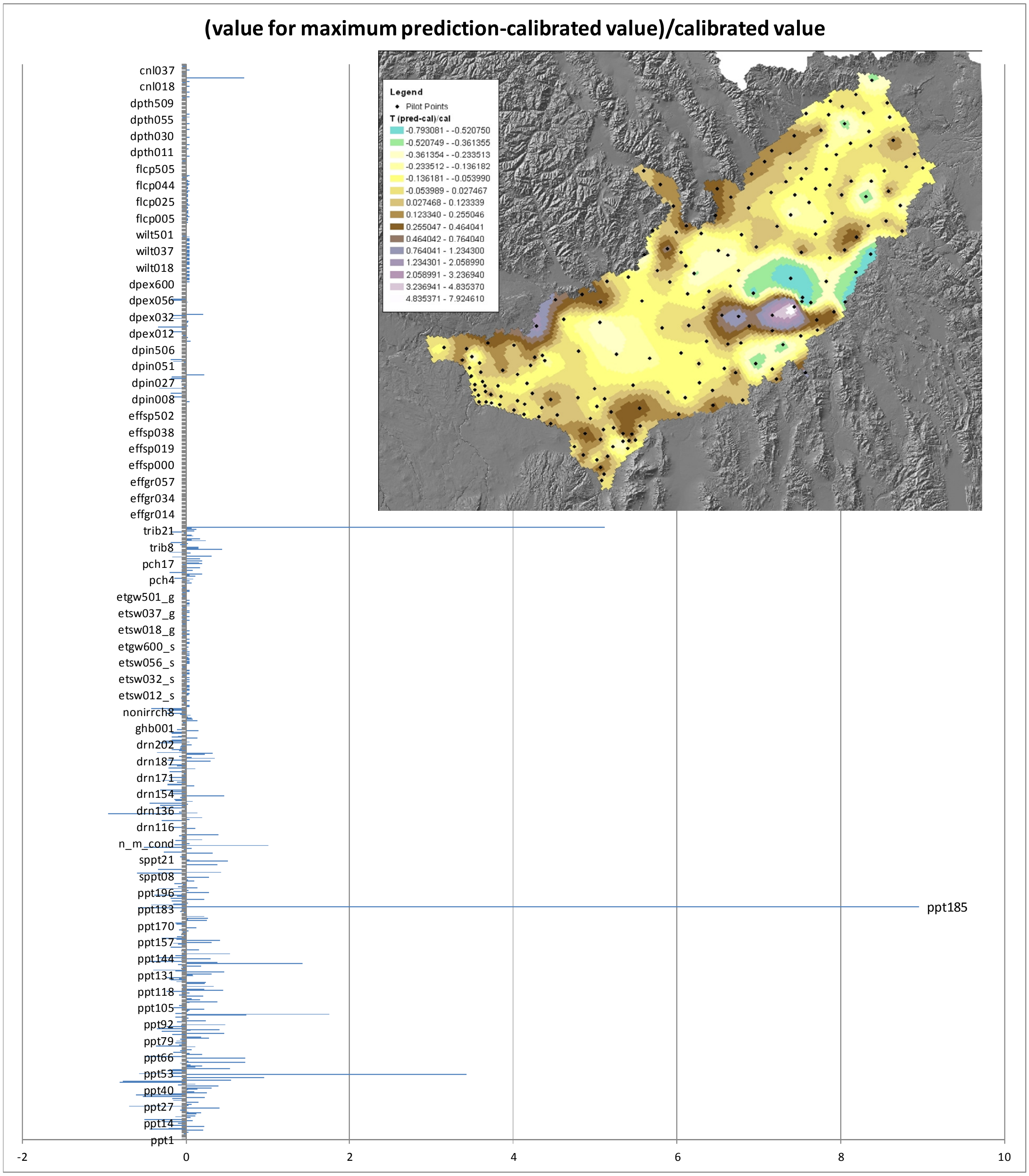


Impact of Water District 130 on Clear Lakes Spring using calibration run E110712A001.

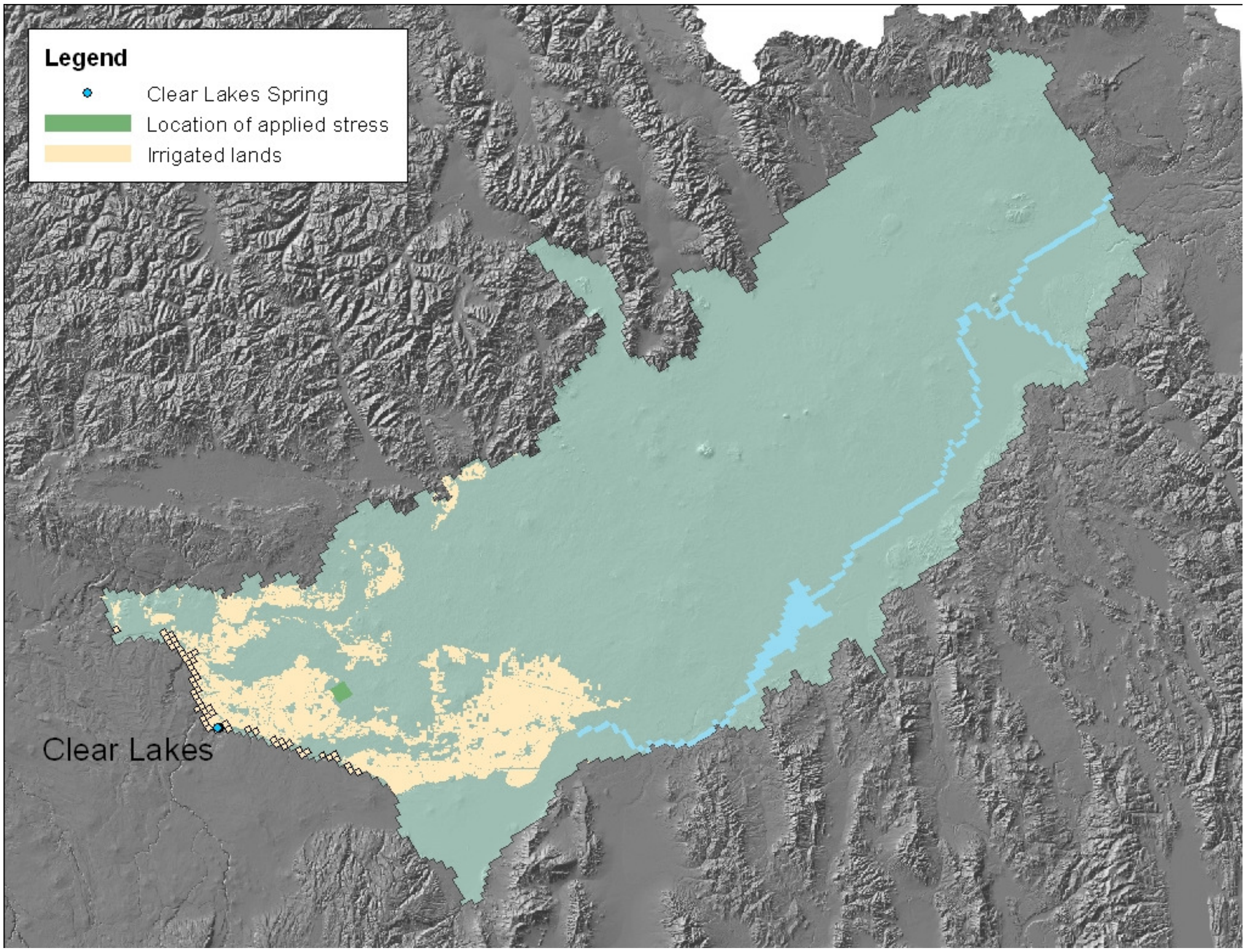




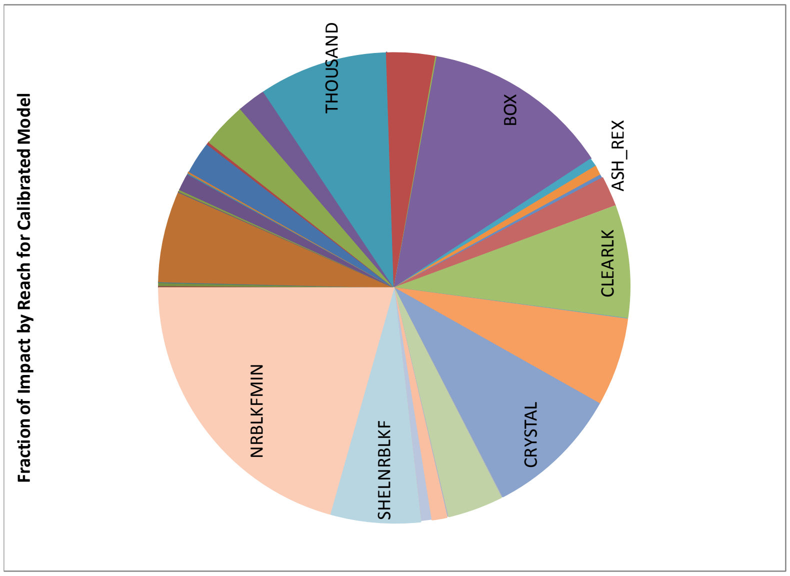
Impact of Water District 130 on Clear Lakes Spring using calibration run E110712A001.

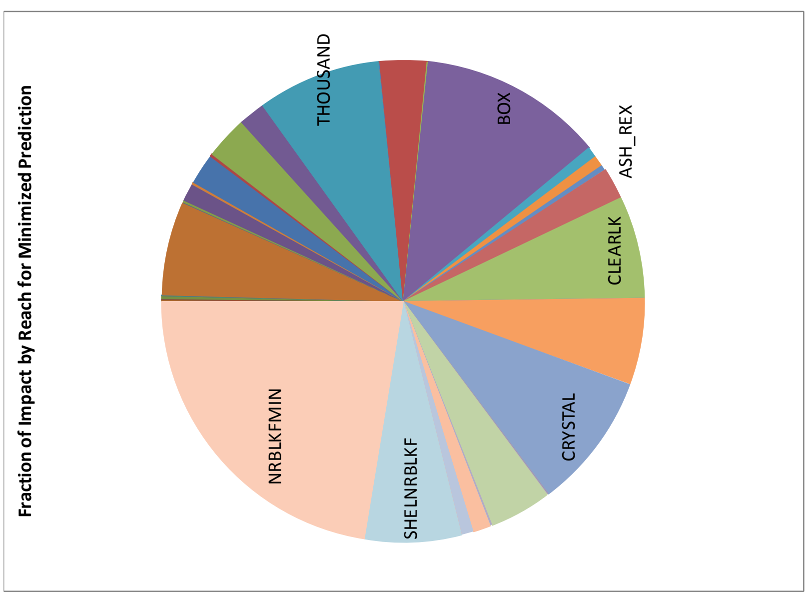


Impact of Water District 130 on Clear Lakes Spring using calibration run E121025A001.

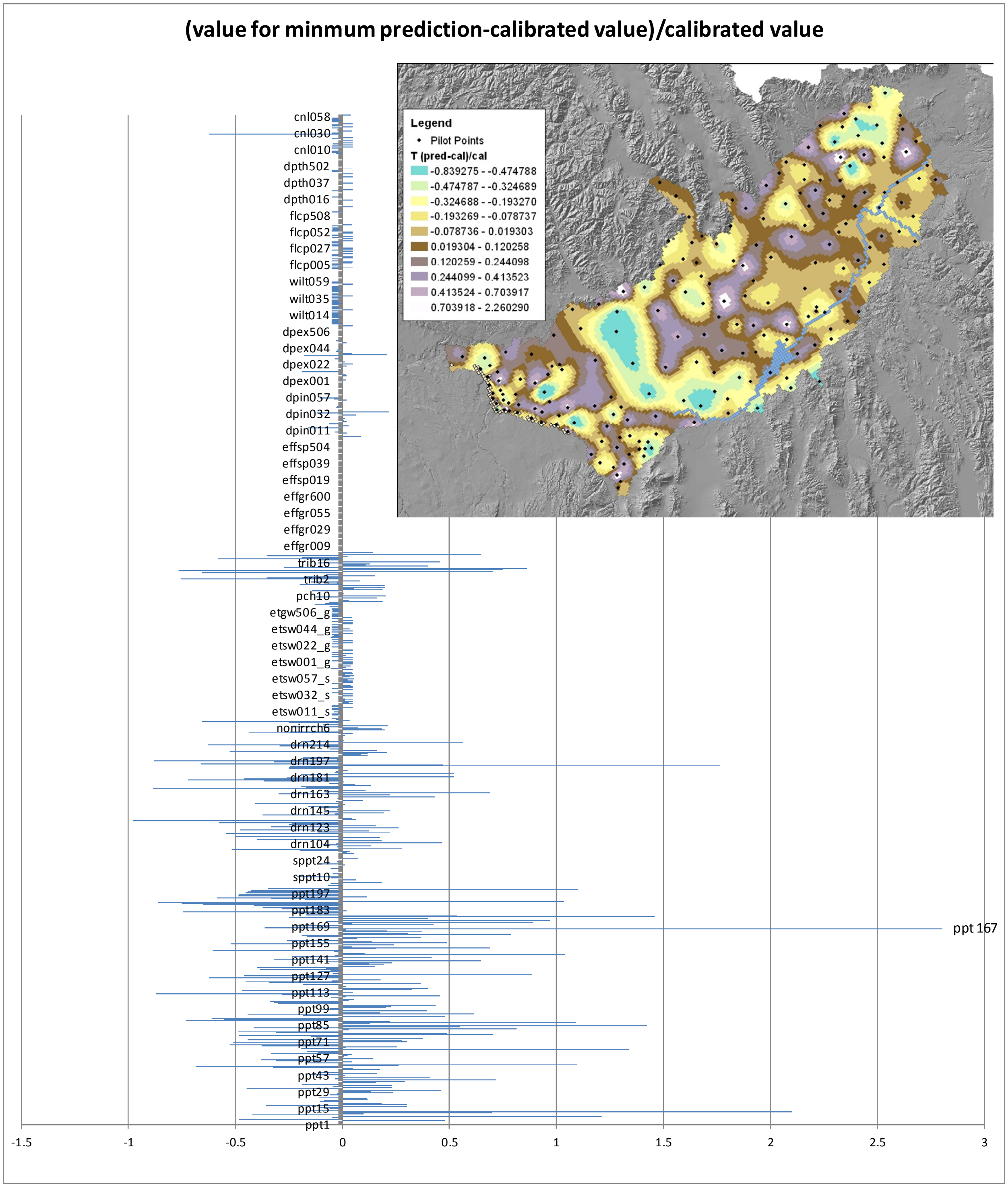


Impact of Water District 130 on Clear Lakes Spring using calibration run E121025A001.

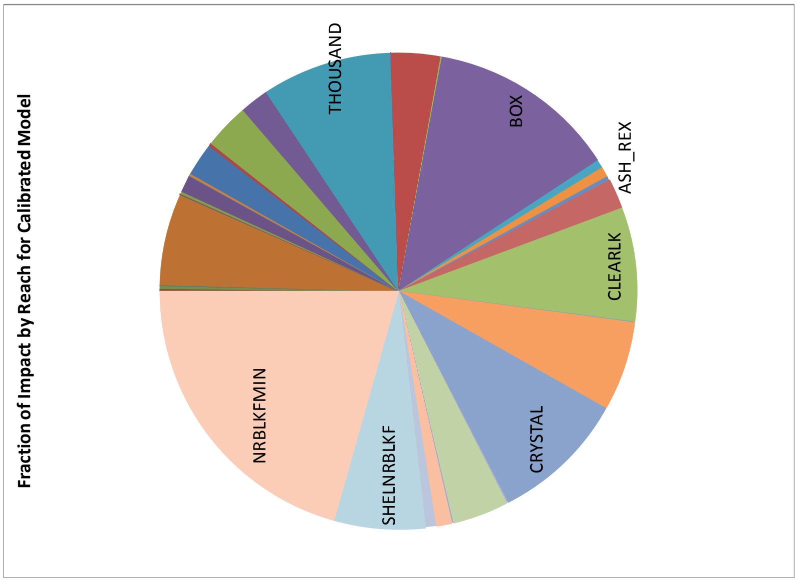


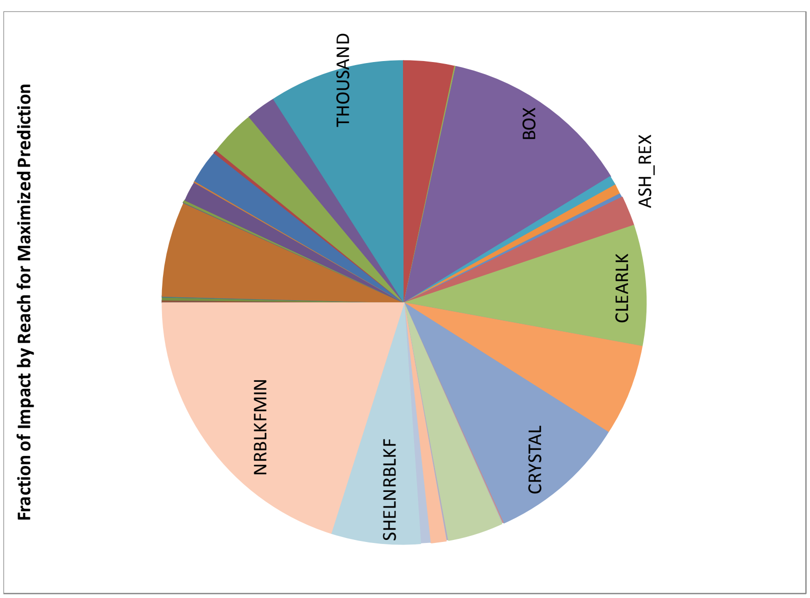


Impact of Water District 130 on Clear Lakes Spring using calibration run E121025A001.

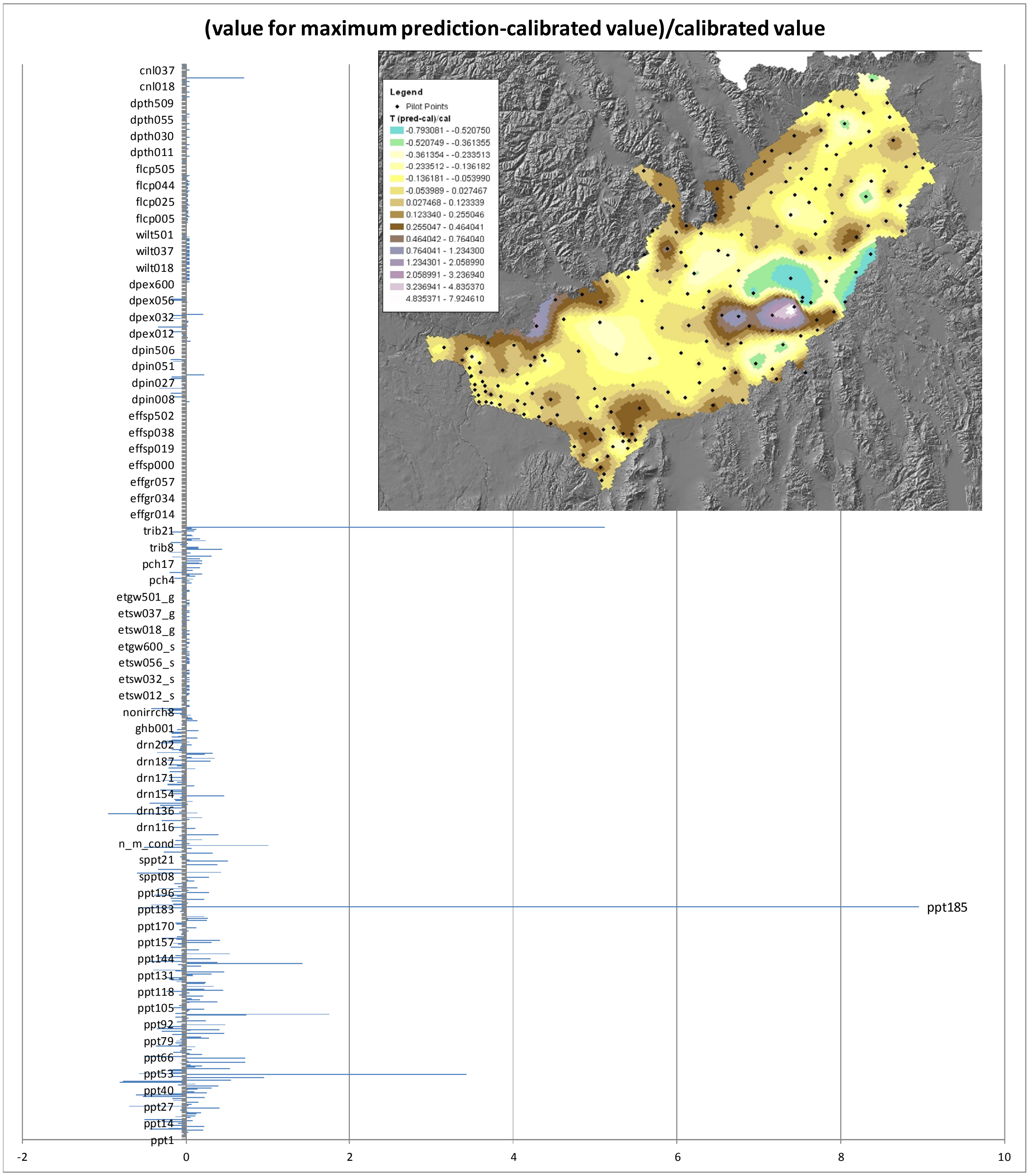


Impact of Water District 130 on Clear Lakes Spring using calibration run E121025A001.

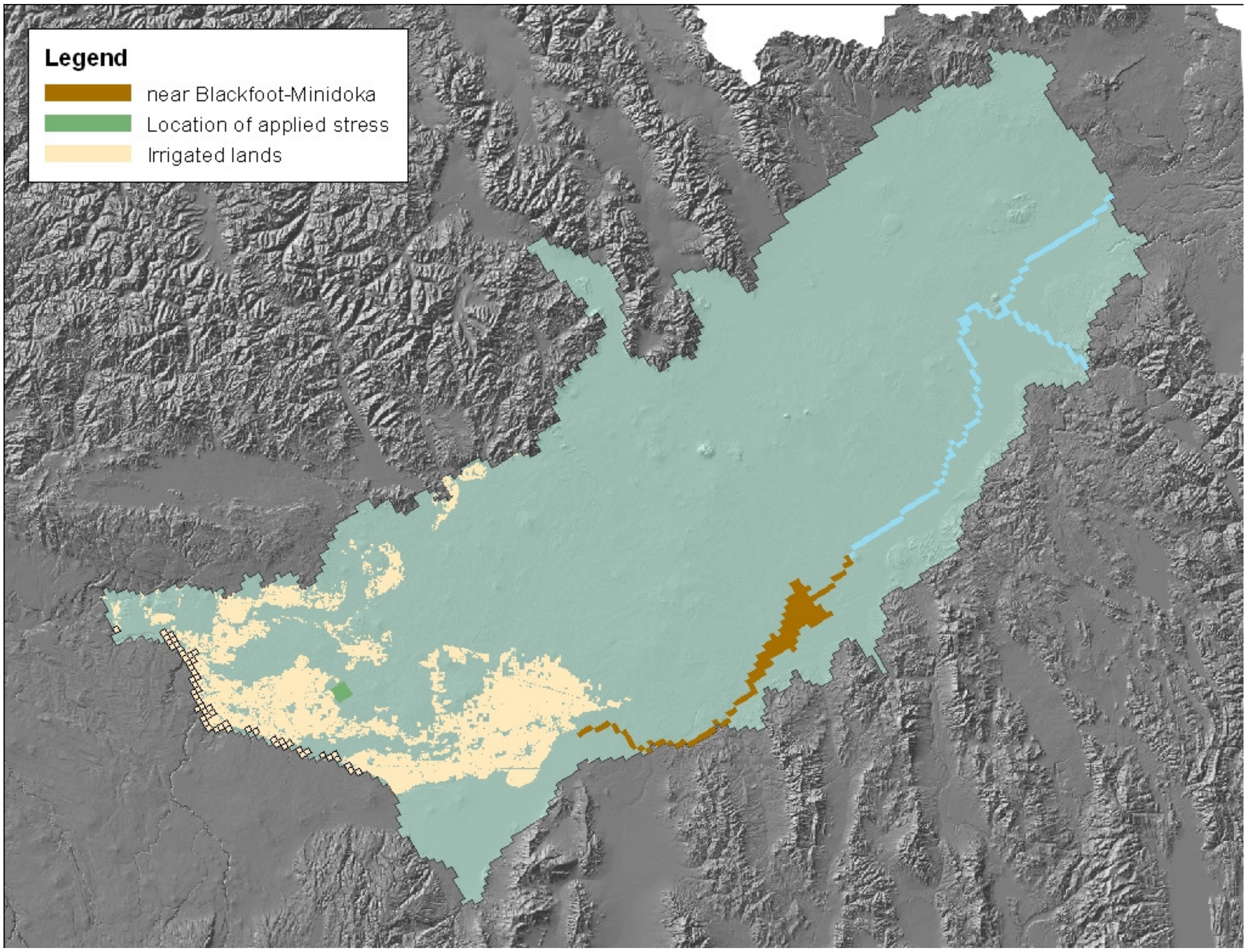




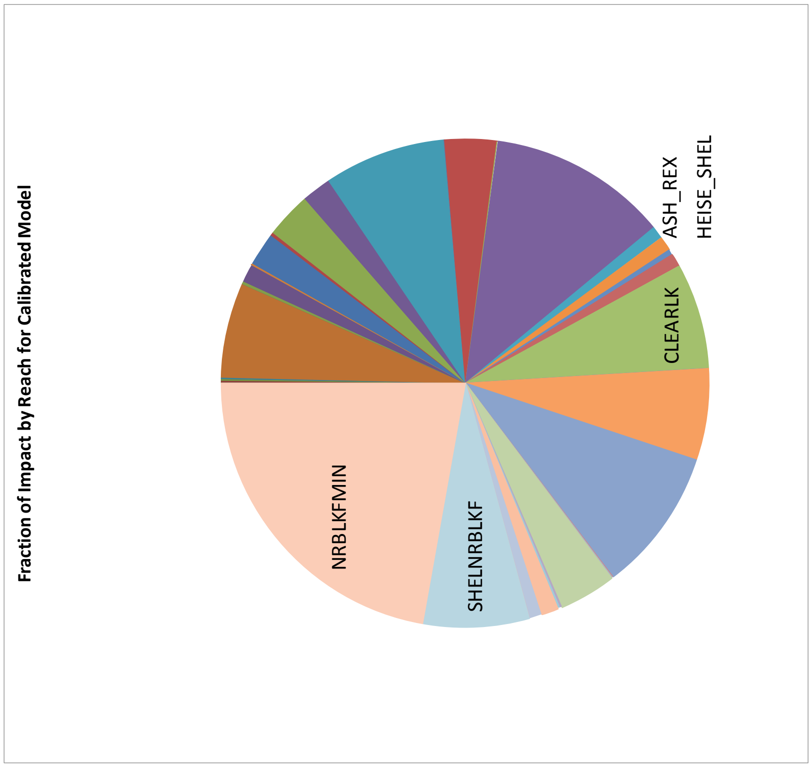
Impact of Water District 130 on Clear Lakes Spring using calibration run E121025A001.

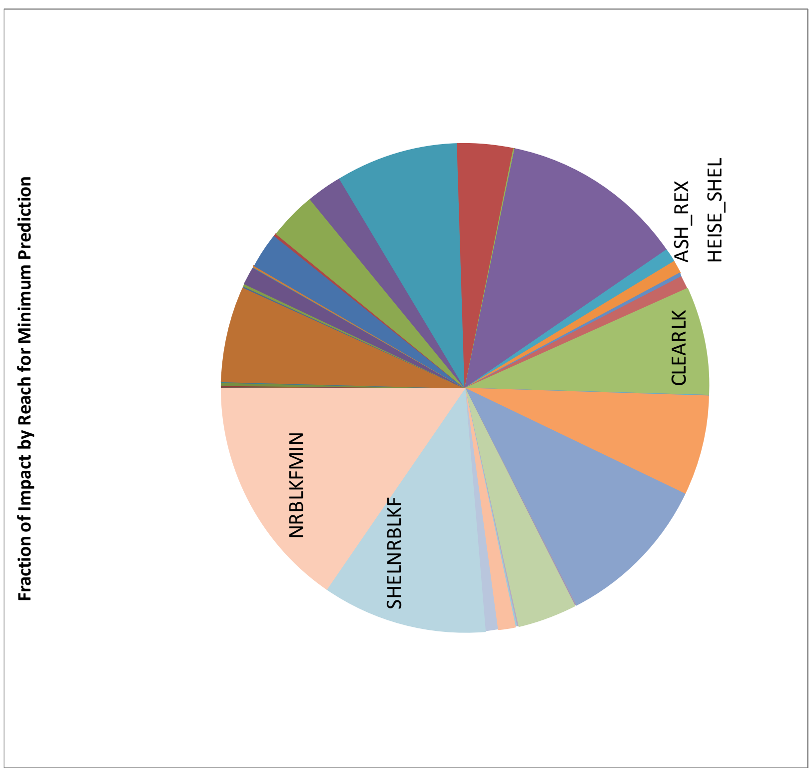


Impact of Water District 130 on near Blackfoot-Minidoka using calibration run E120116A008.

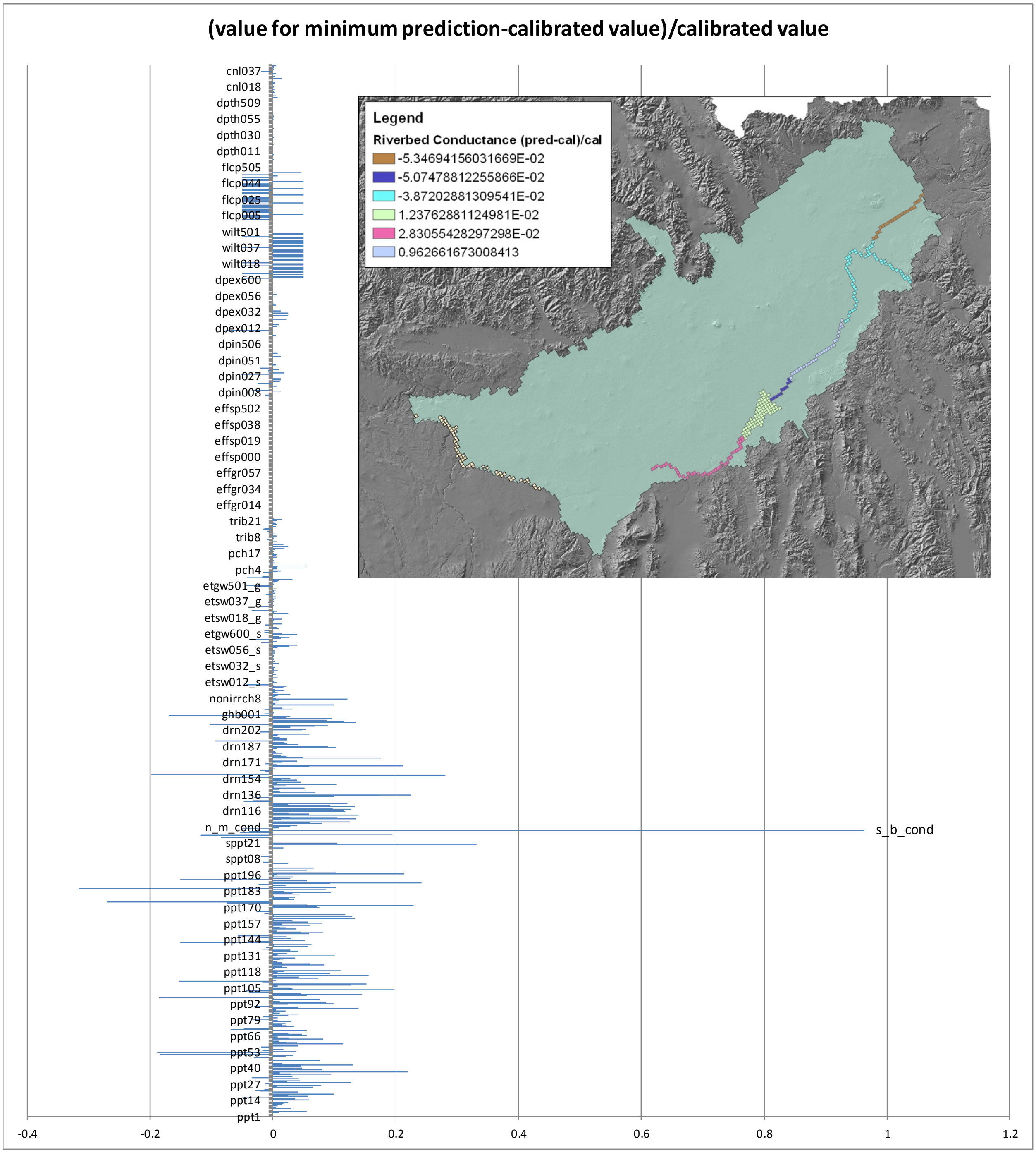


Impact of Water District 130 on near Blackfoot-Minidoka using calibration run E120116A008.

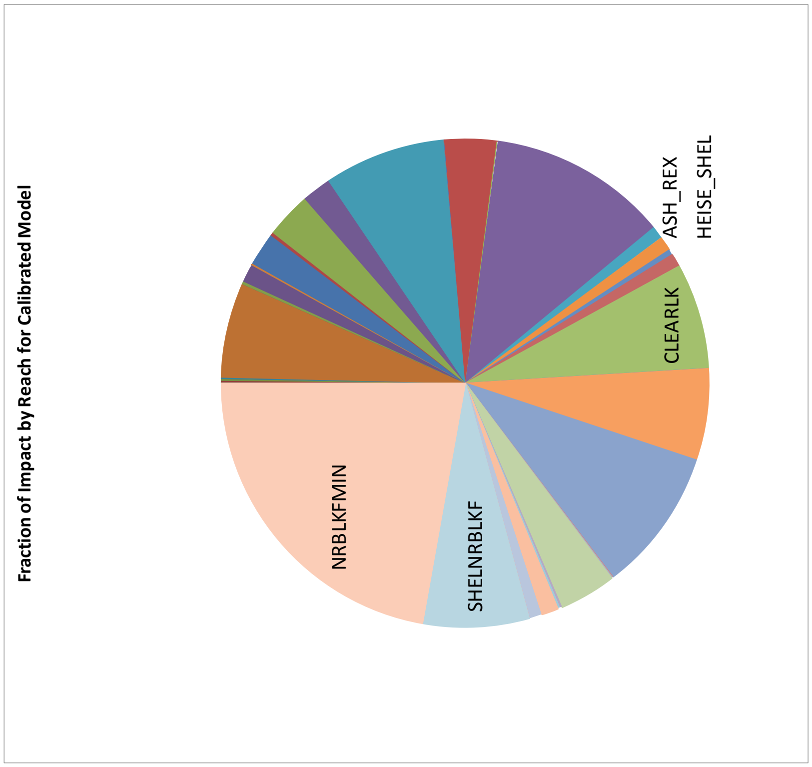


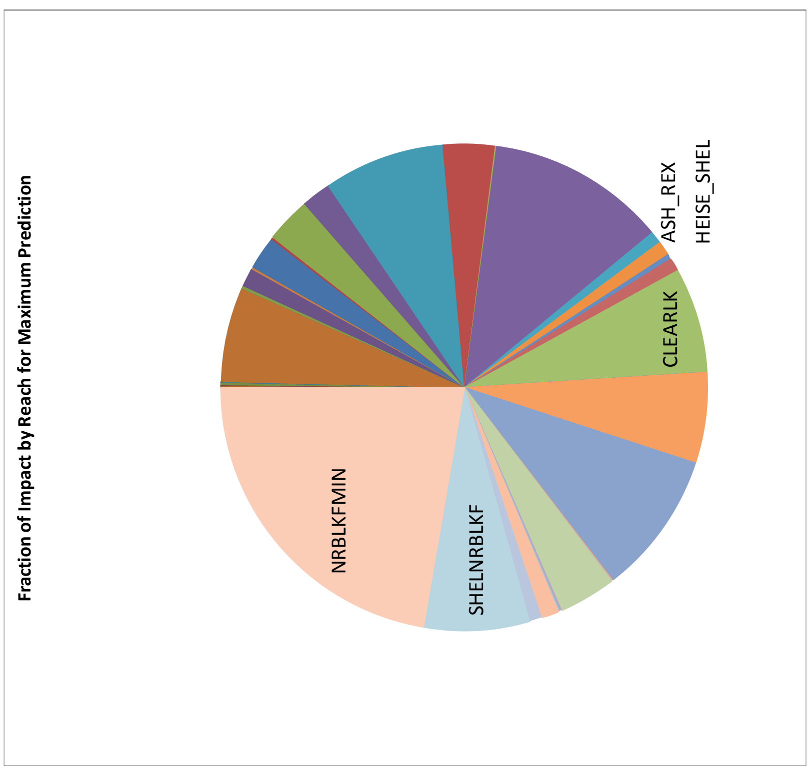


Impact of Water District 130 on near Blackfoot-Minidoka using calibration run E120116A008.

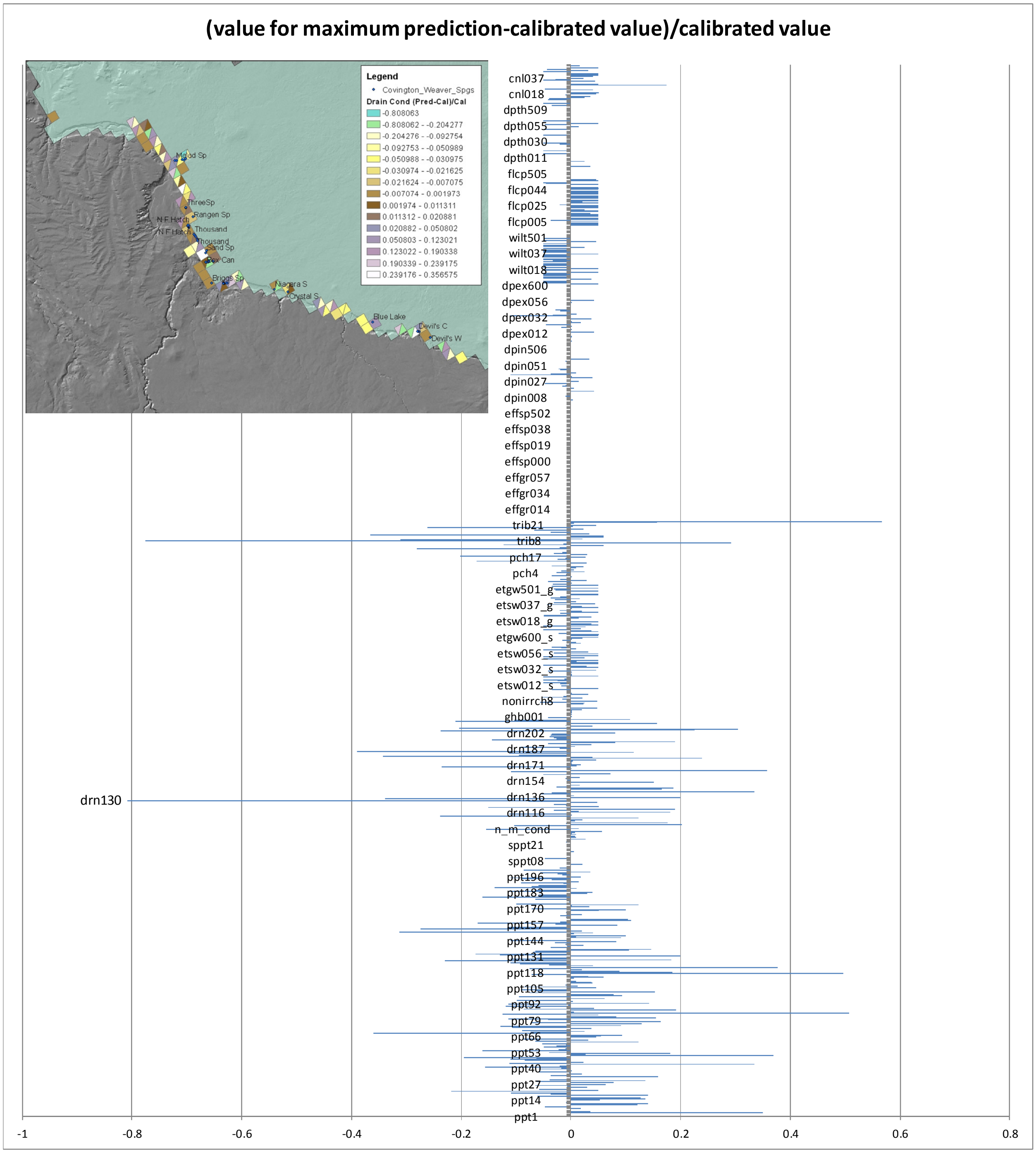


Impact of Water District 130 on near Blackfoot-Minidoka using calibration run E120116A008.

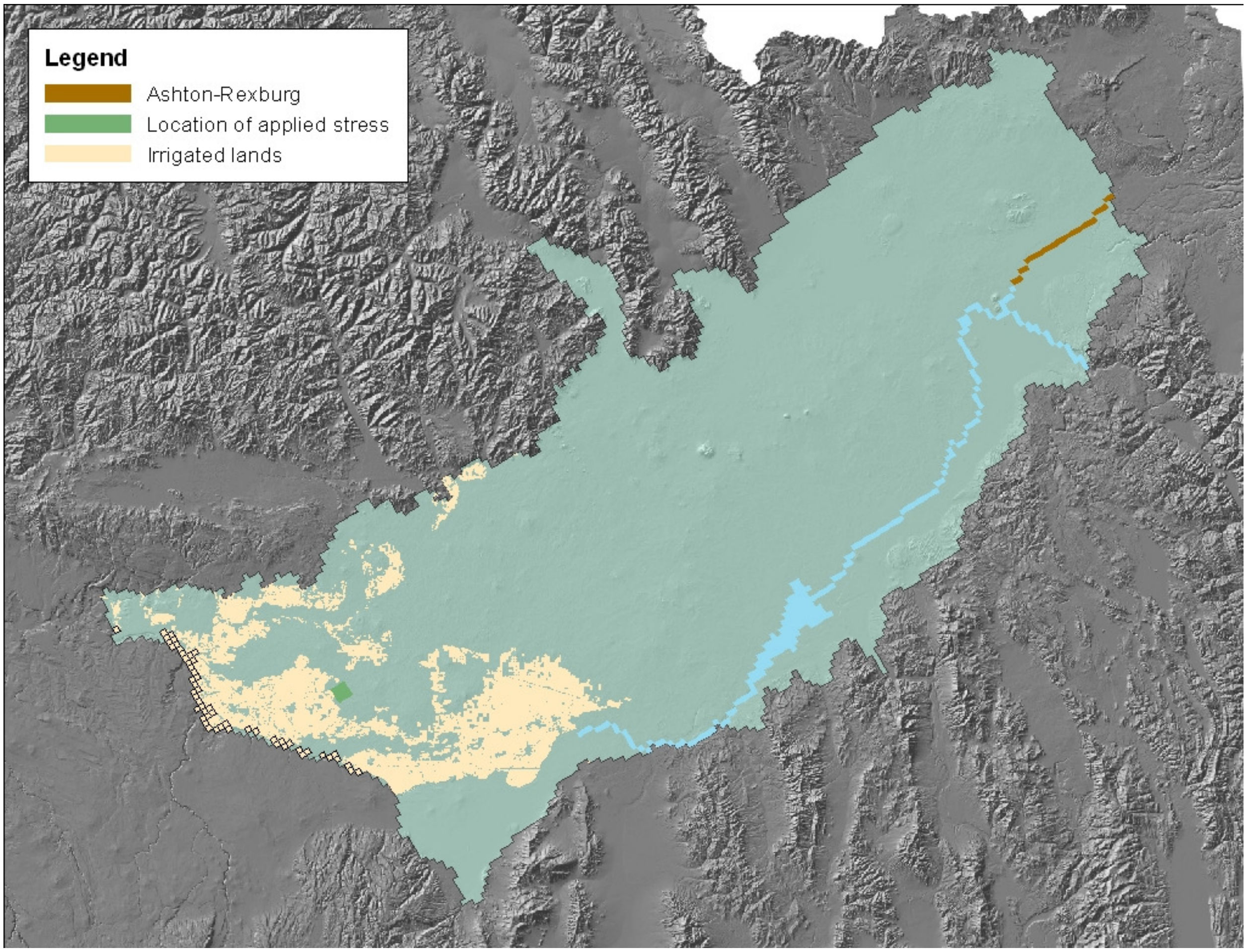




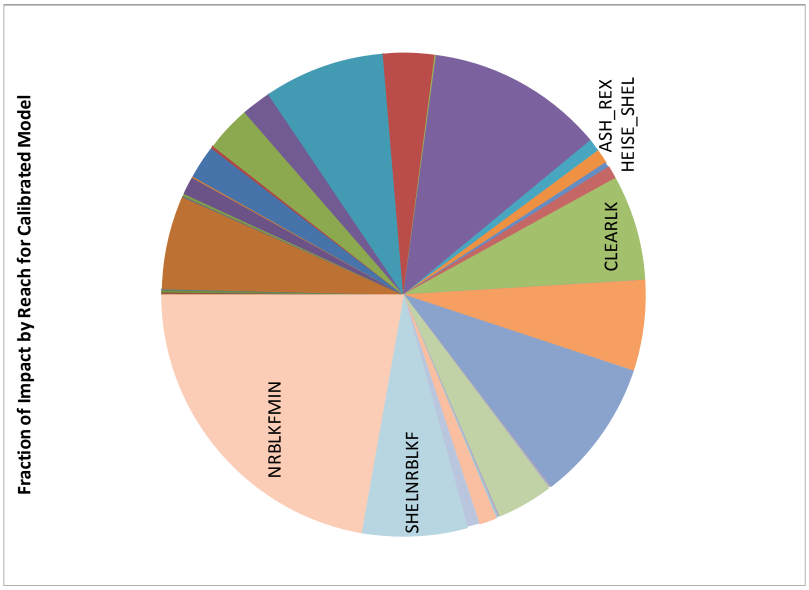
Impact of Water District 130 on near Blackfoot-Minidoka using calibration run E120116A008.

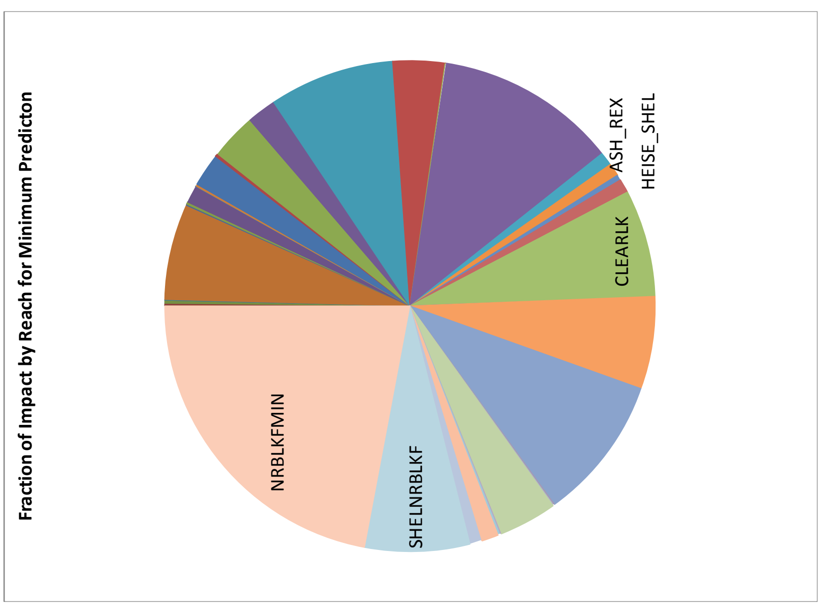


Impact of Water District 130 on Ashton-Rexburg using calibration run E120116A008.

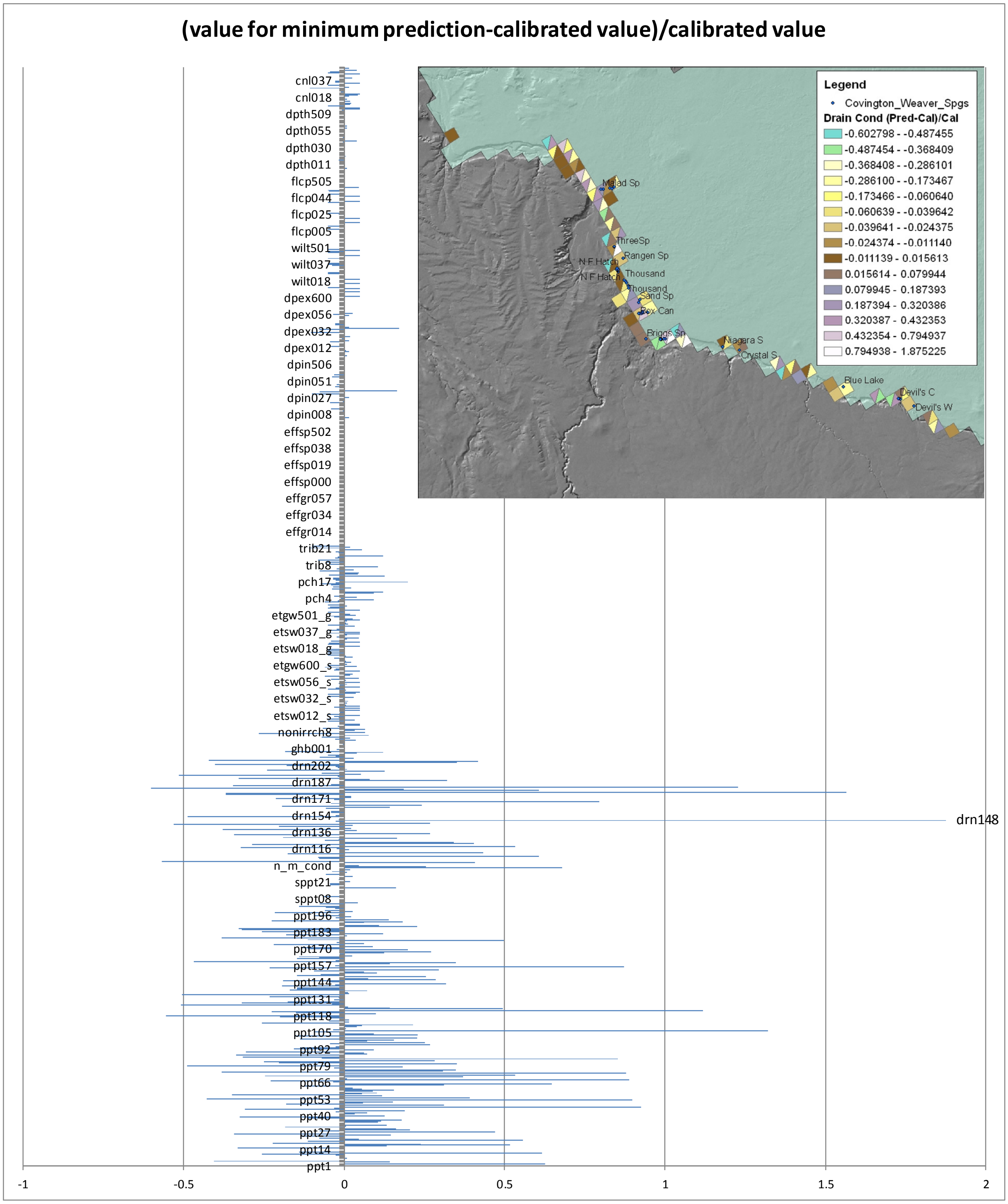


Impact of Water District 130 on Ashton-Rexburg using calibration run E120116A008.





Impact of Water District 130 on Ashton-Rexburg using calibration run E120116A008.



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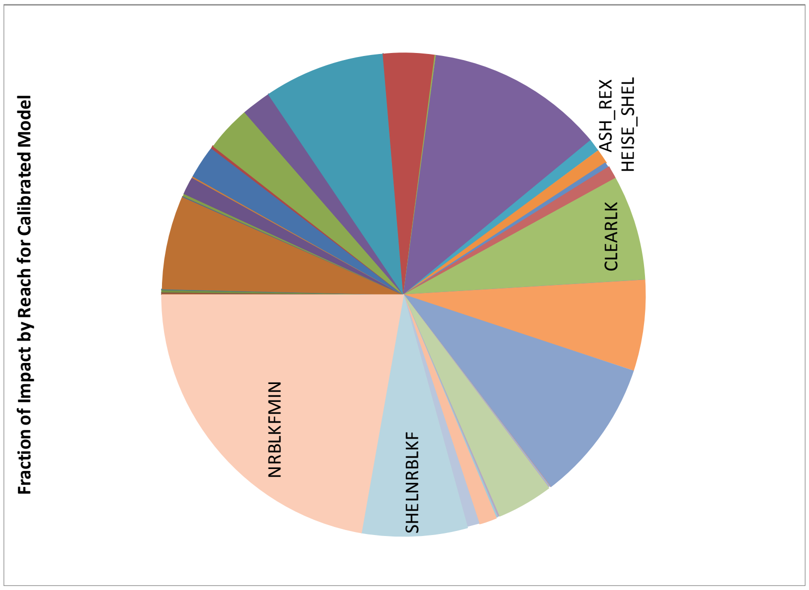

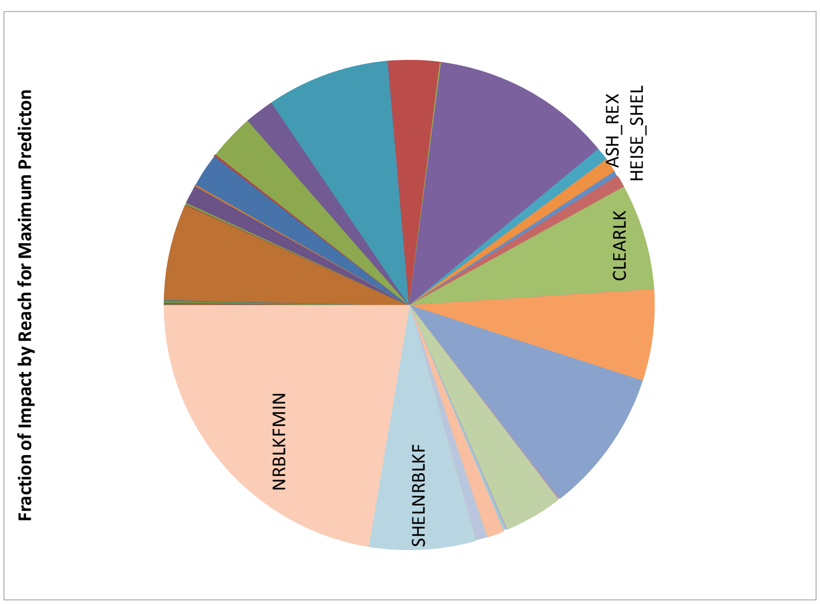

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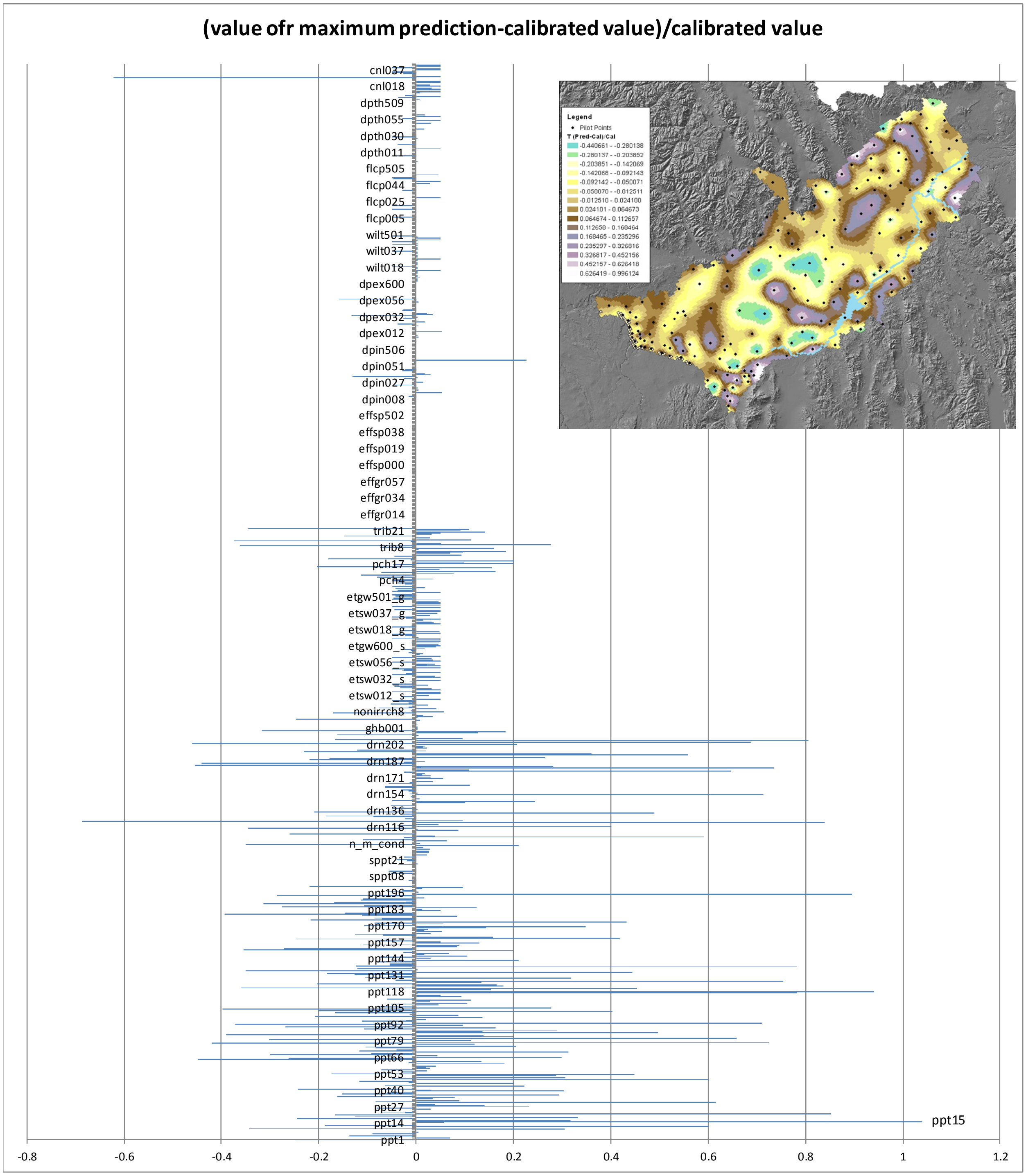
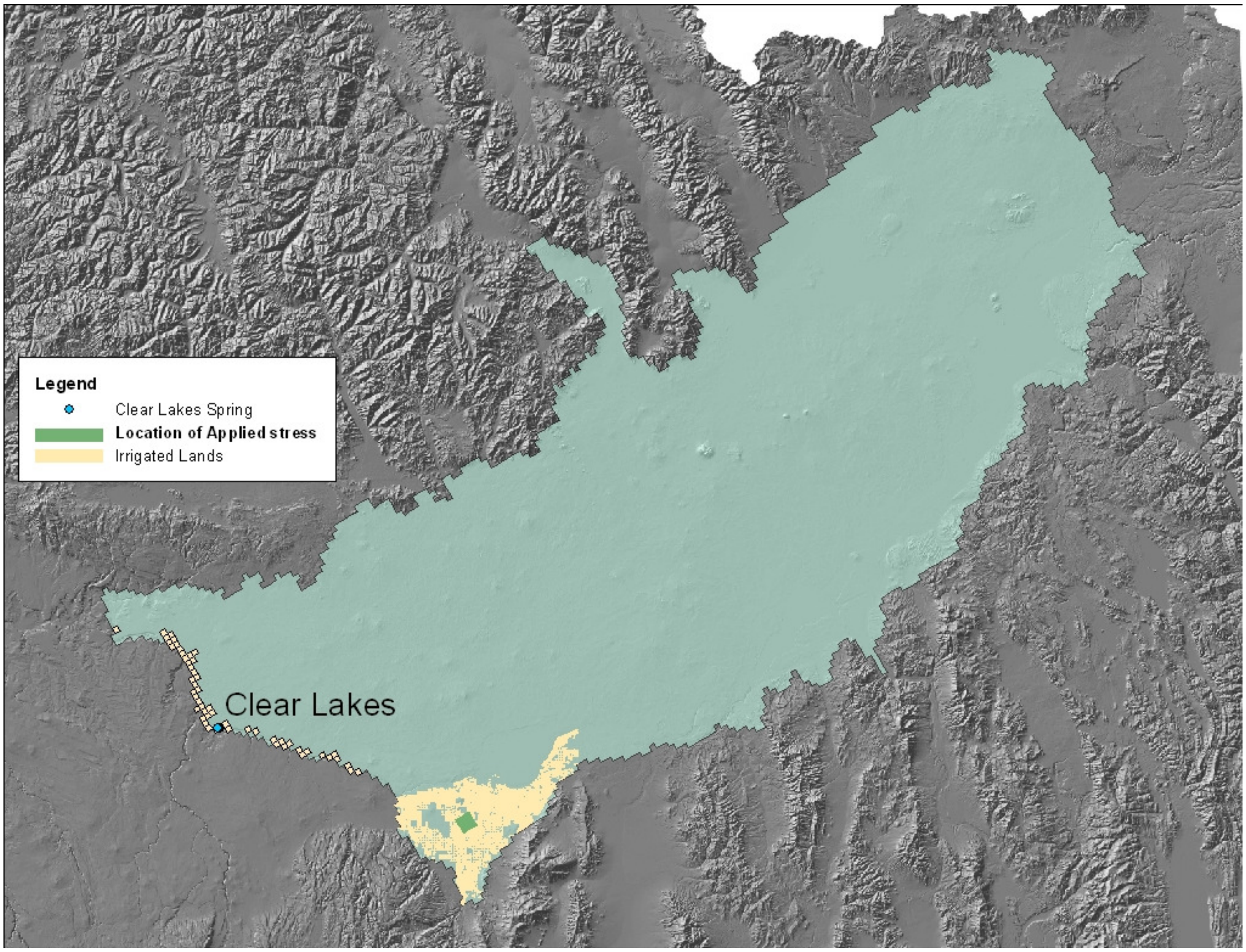
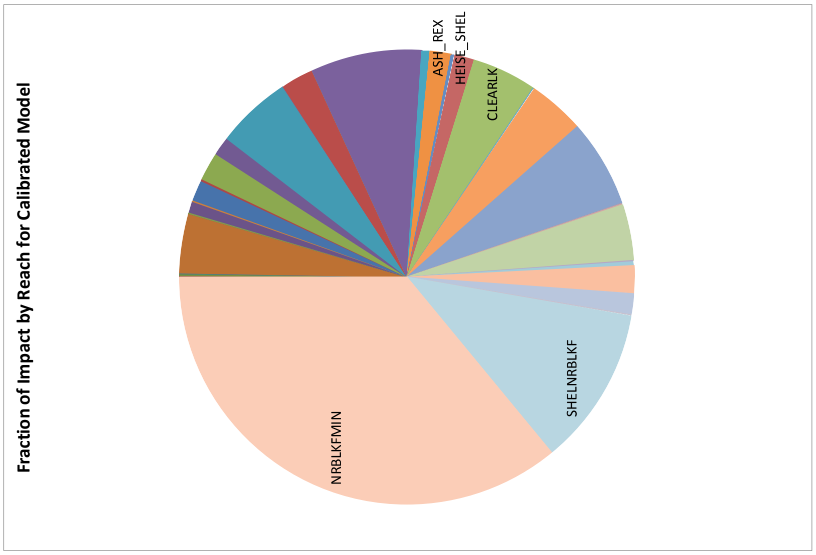
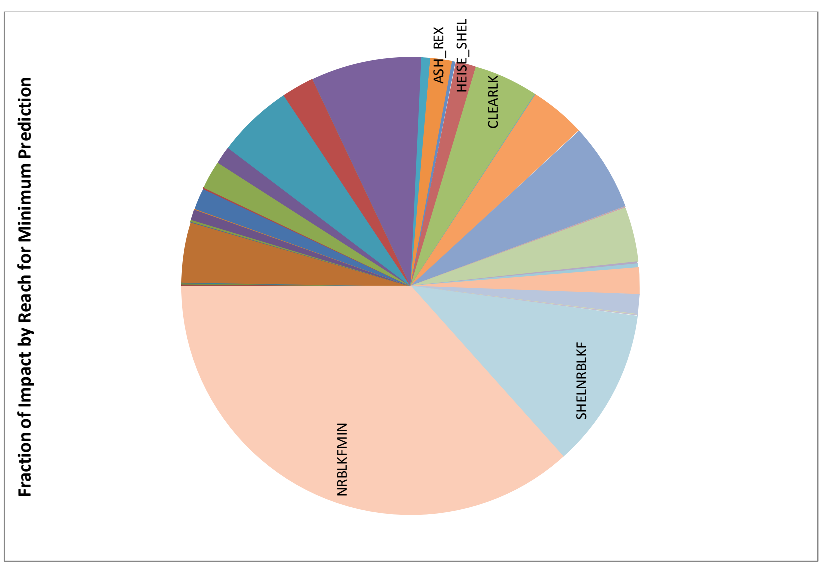


Impact of Water District 140 on Clear Lakes Spring using calibration run E120116A008.

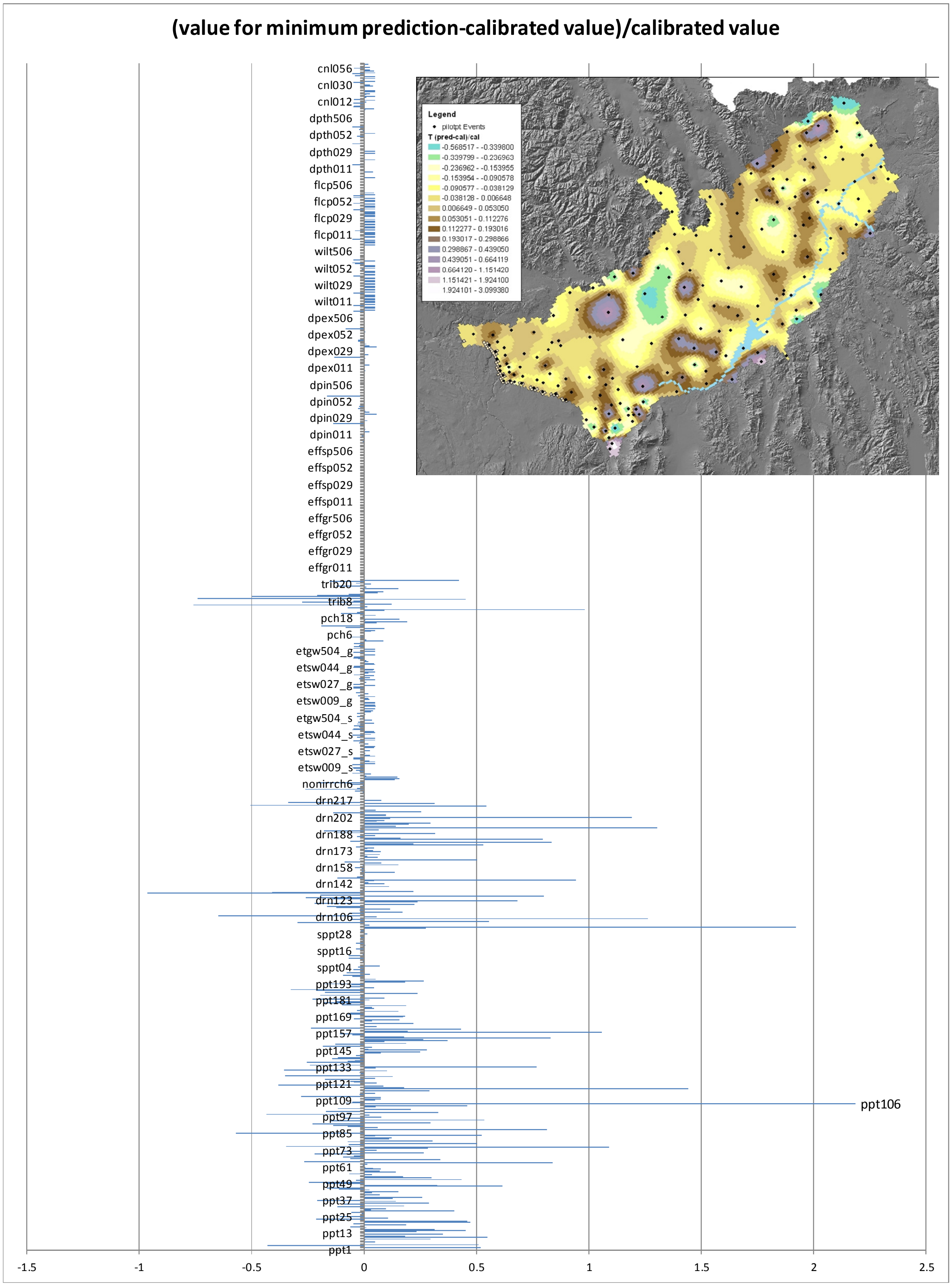


Impact of Water District 140 on Clear Lakes Spring using calibration run E120116A008.

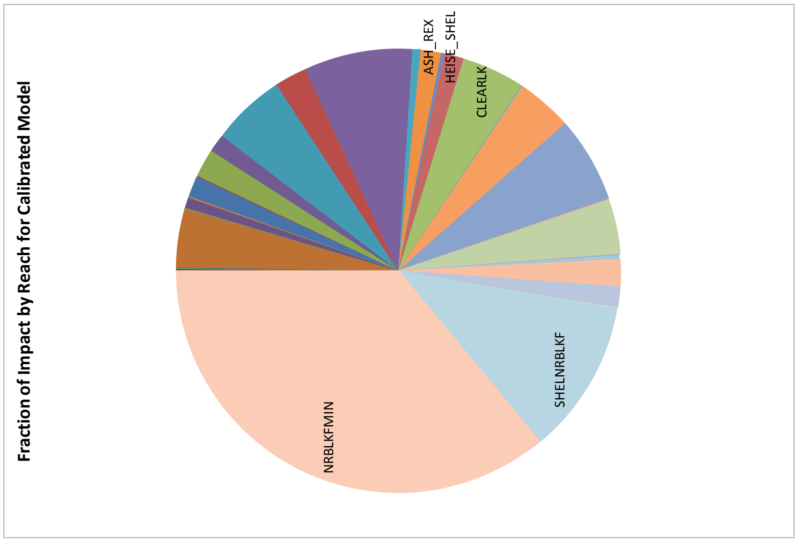


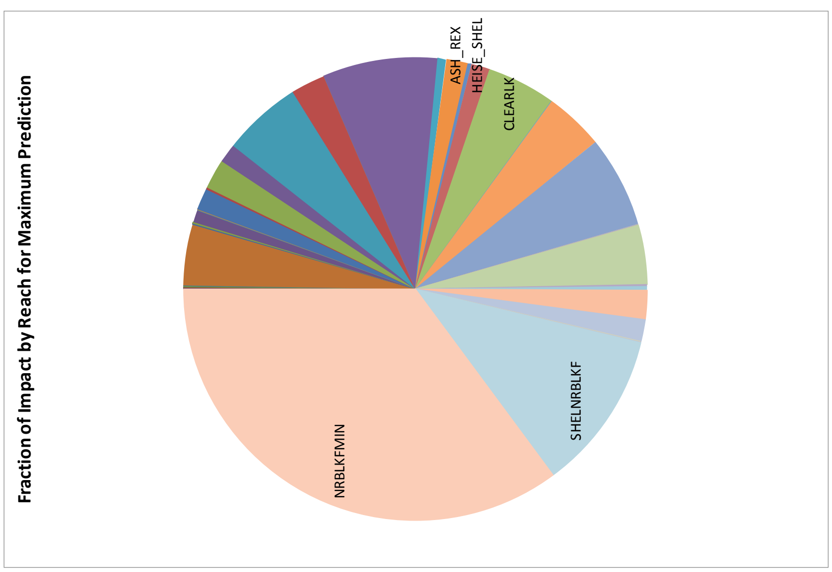


Impact of Water District 140 on Clear Lakes Spring using calibration run E120116A008.

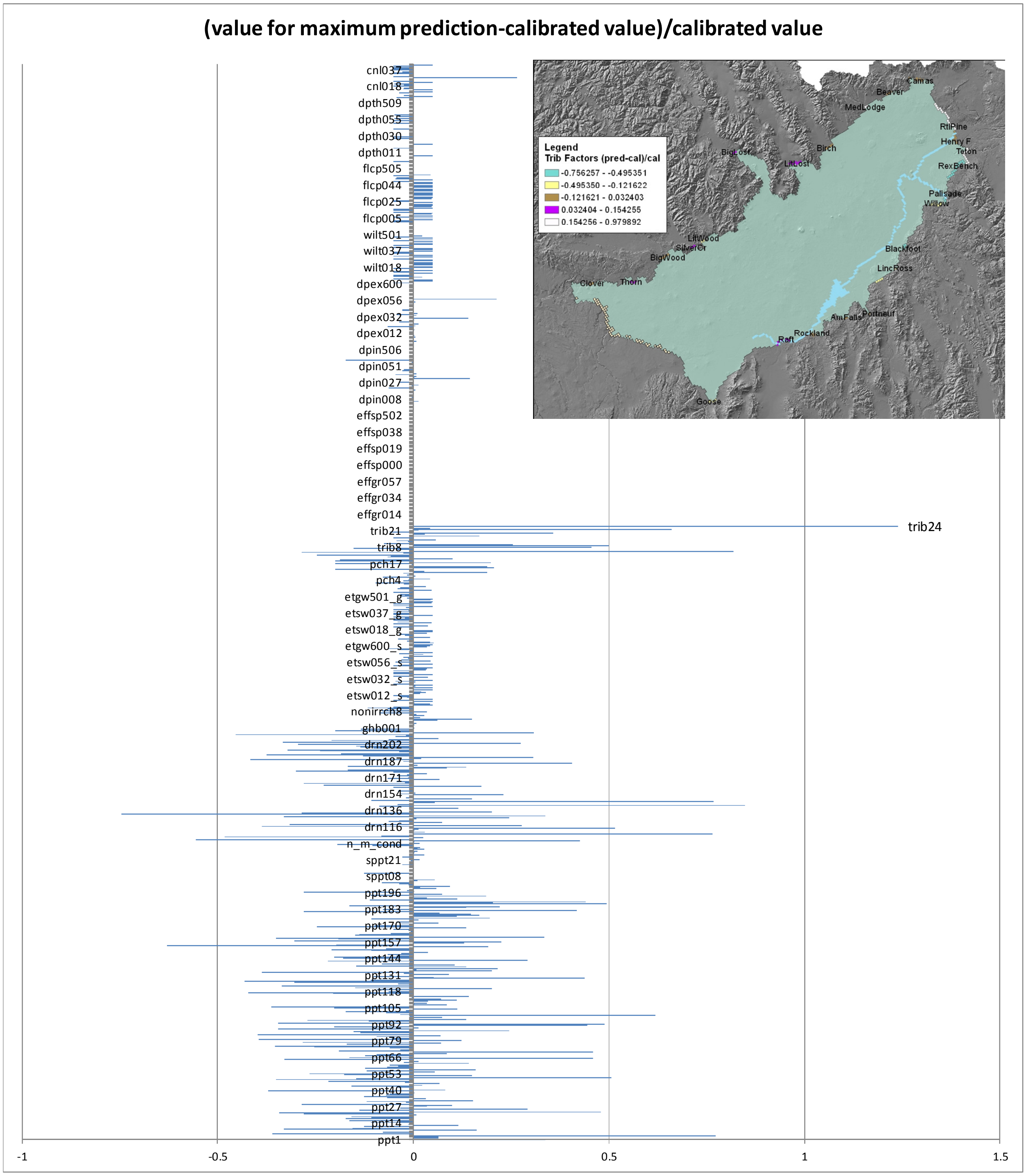


Impact of Water District 140 on Clear Lakes Spring using calibration run E120116A008.

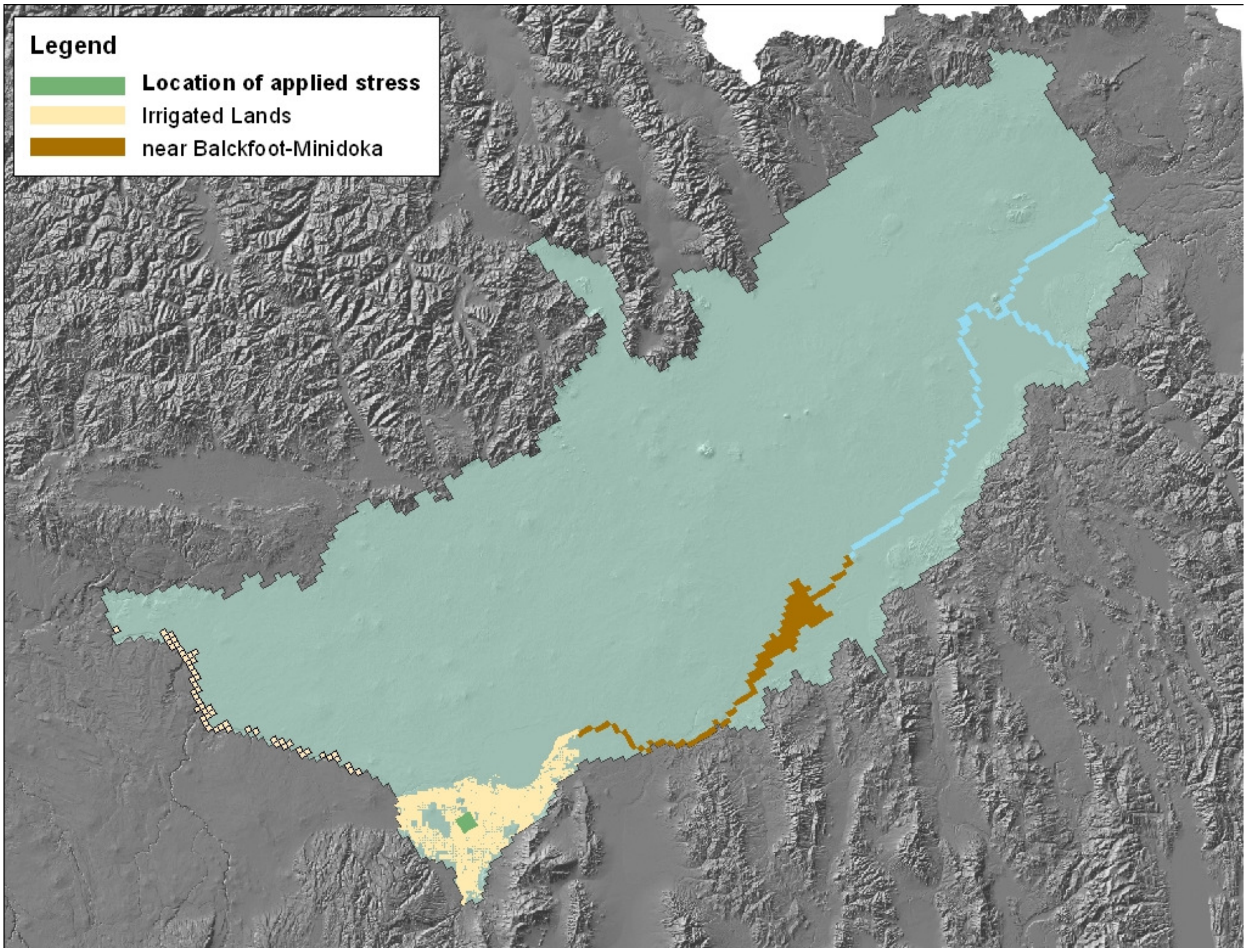




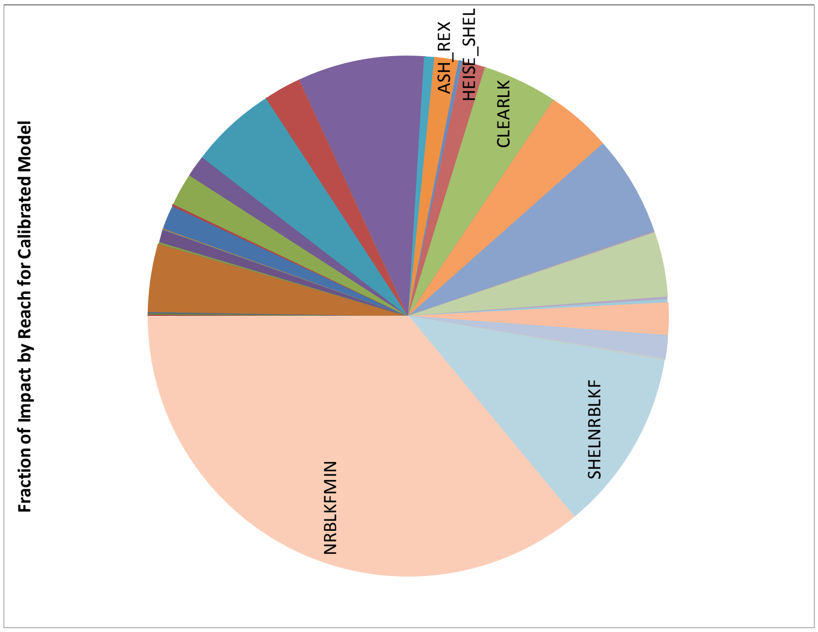
Impact of Water District 140 on Clear Lakes Spring using calibration run E120116A008.

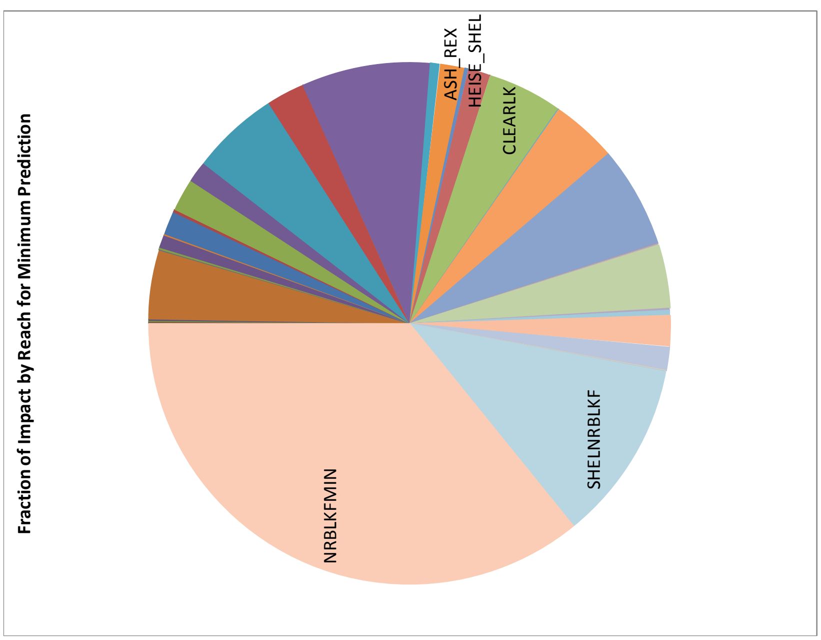


Impact of Water District 140 on near Blackfoot-Minidoka using calibration run E120116A008.

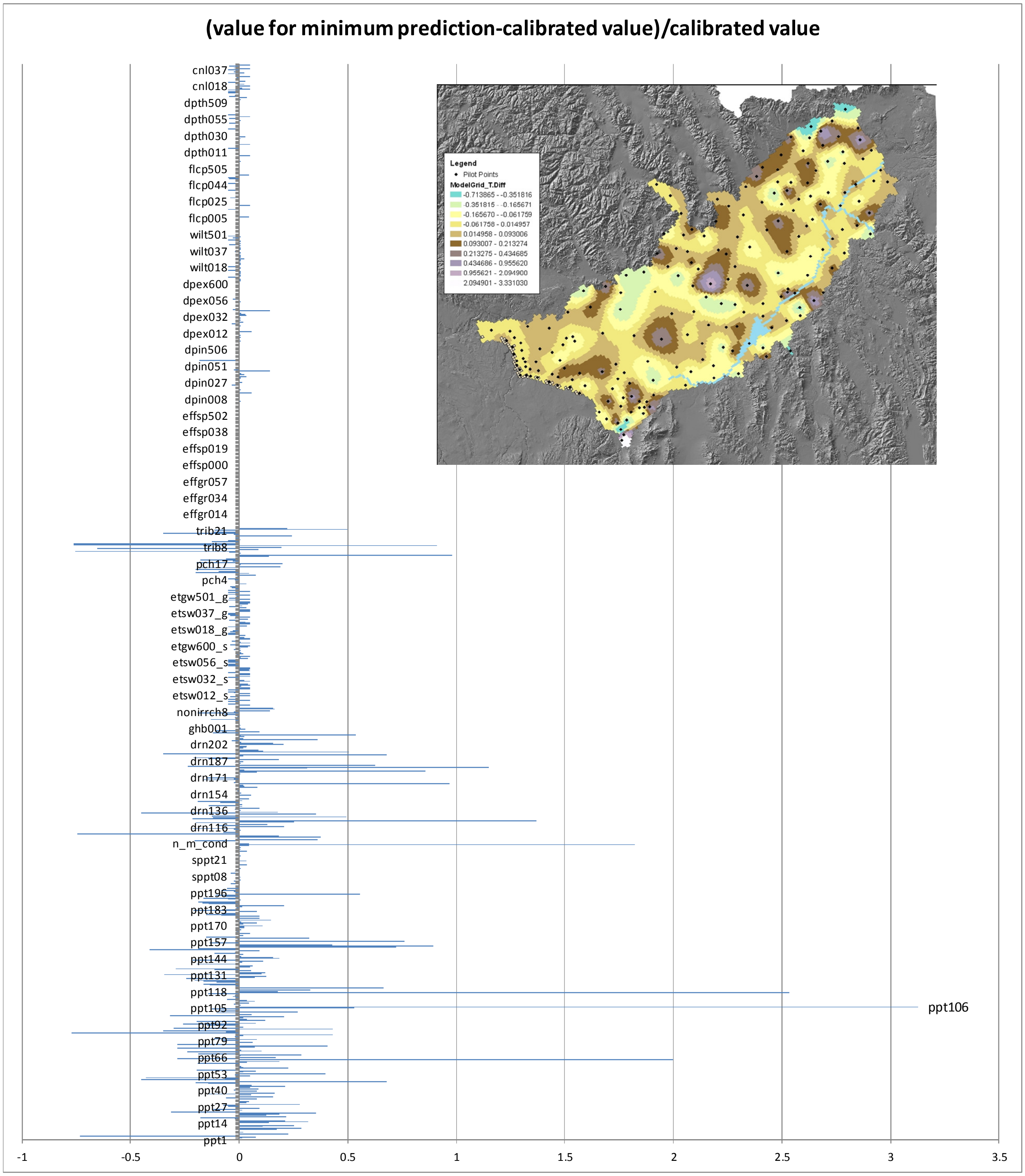


Impact of Water District 140 on near Blackfoot-Minidoka using calibration run E120116A008.

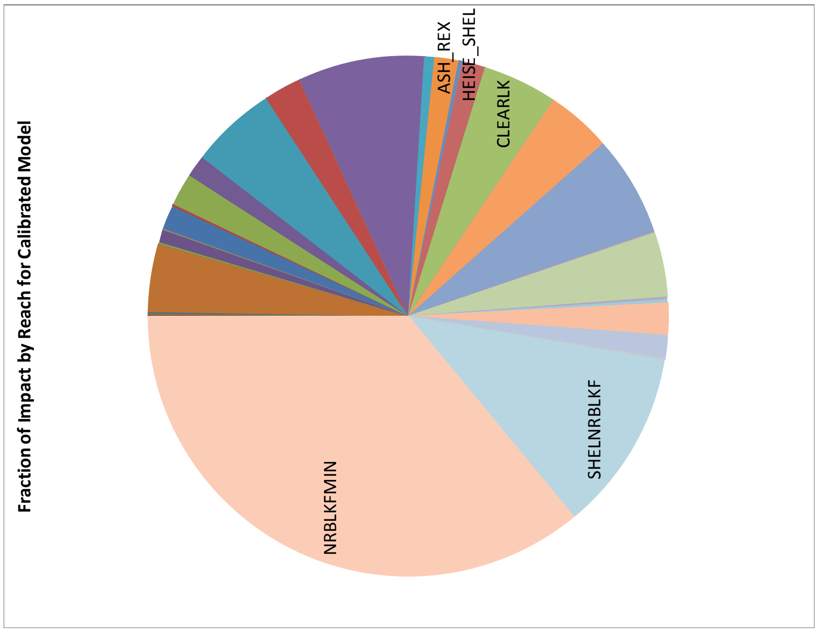


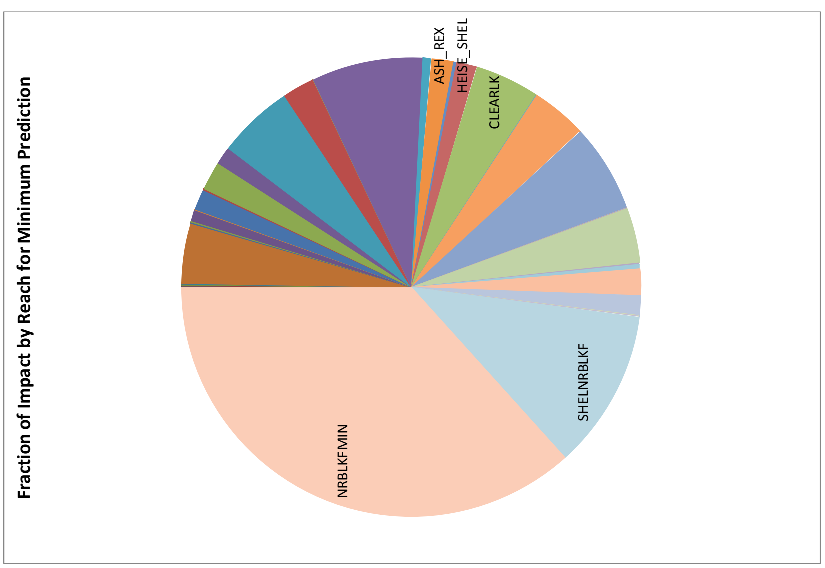


Impact of Water District 140 on near Blackfoot-Minidoka using calibration run E120116A008.

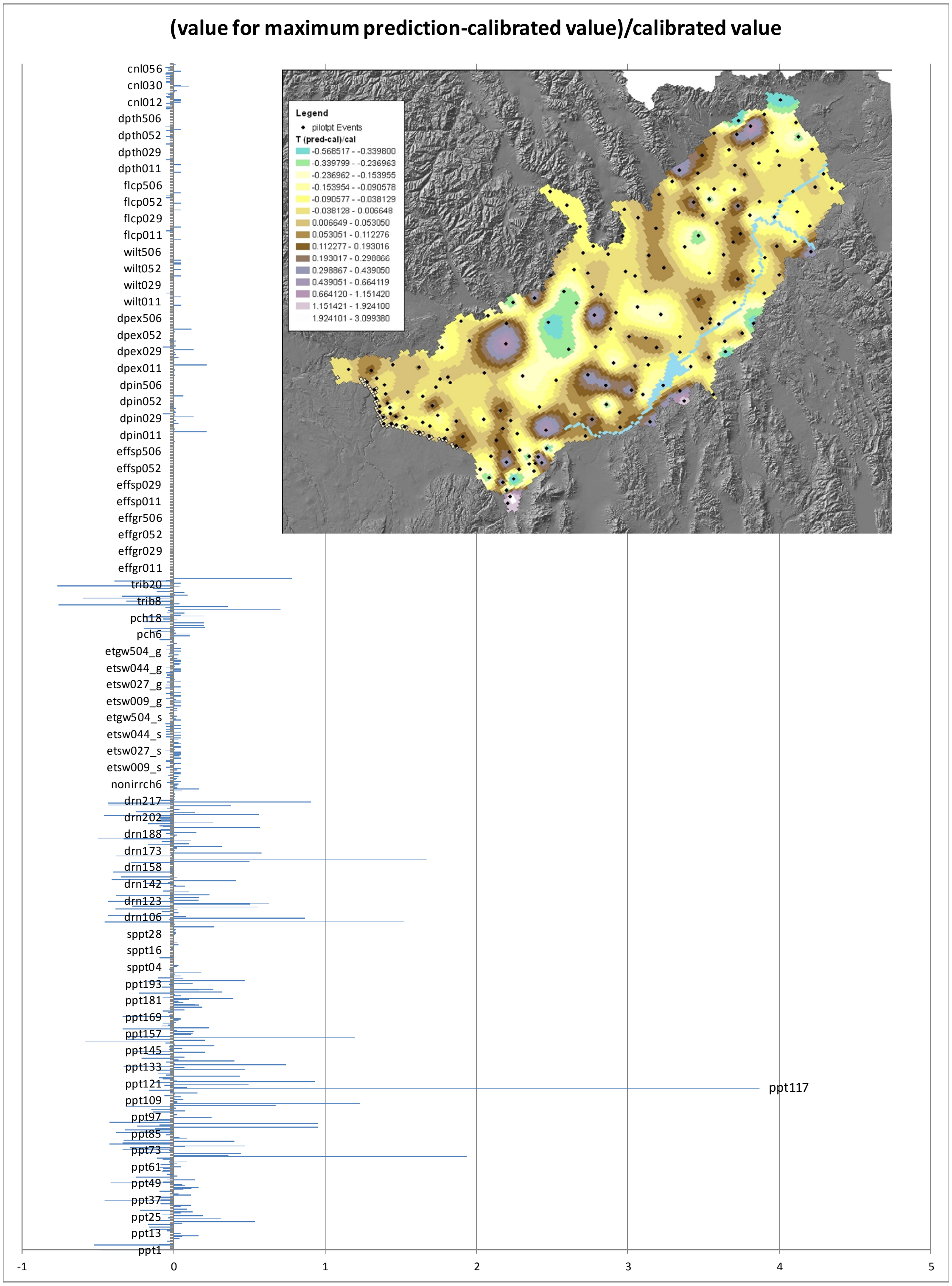


Impact of Water District 140 on near Blackfoot-Minidoka using calibration run E120116A008.



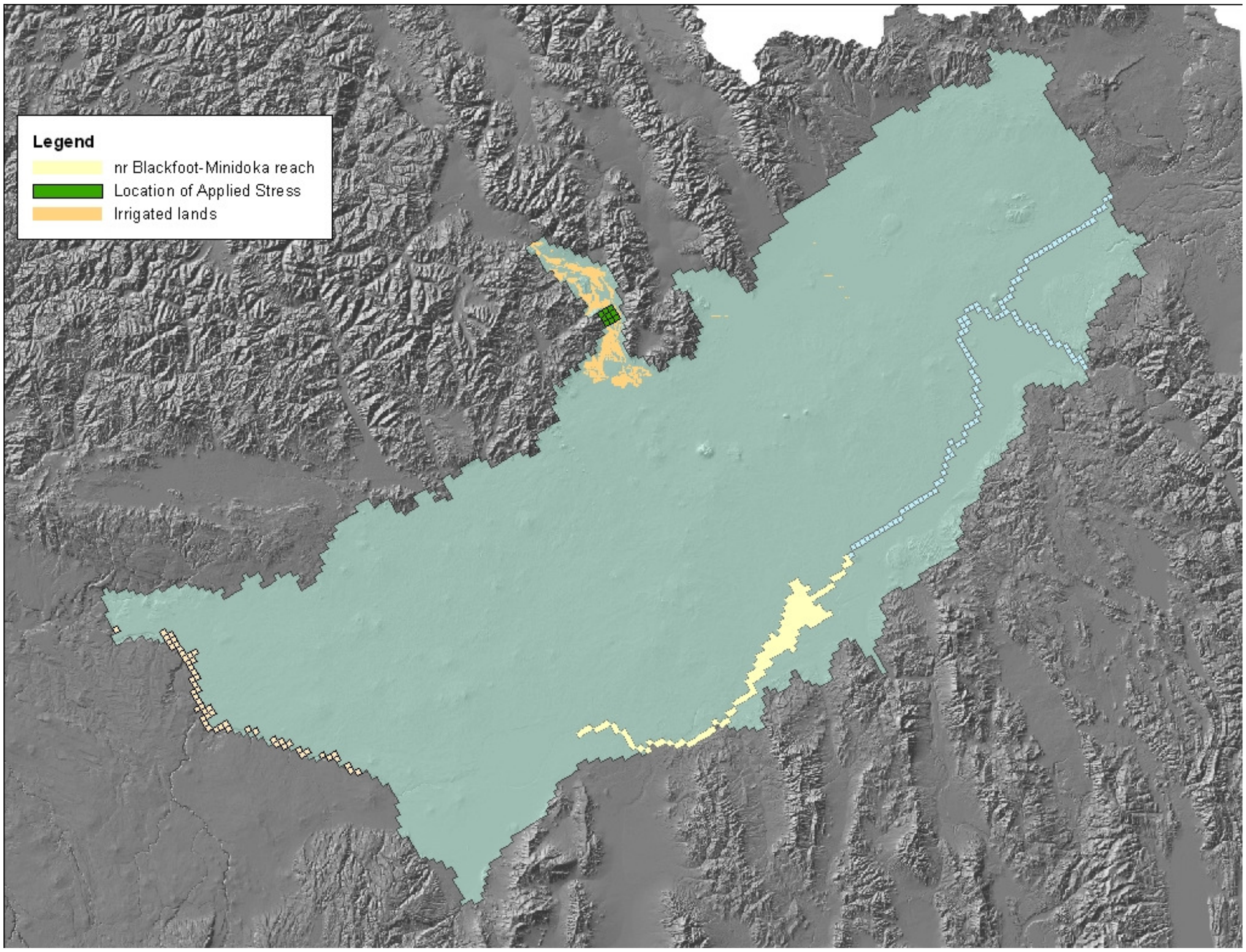


Impact of Water District 140 on near Blackfoot-Minidoka using calibration run E120116A008.

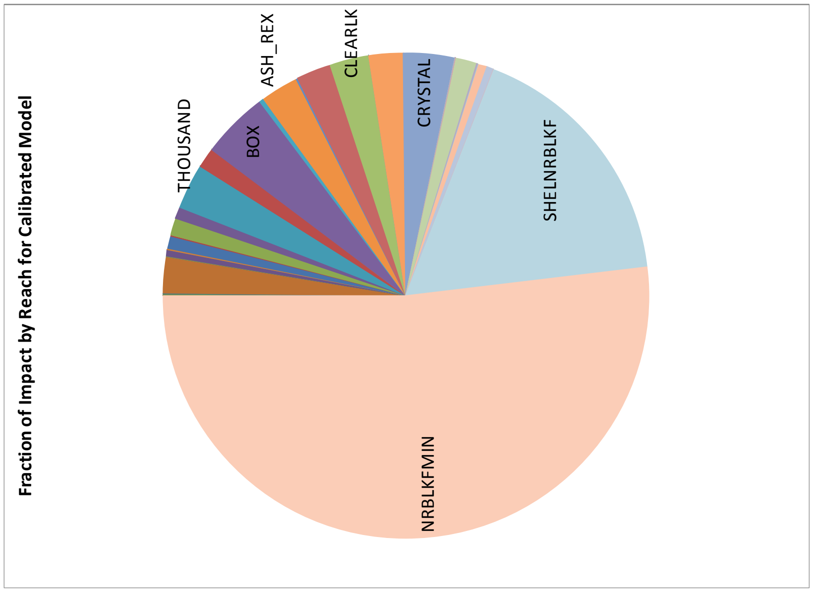


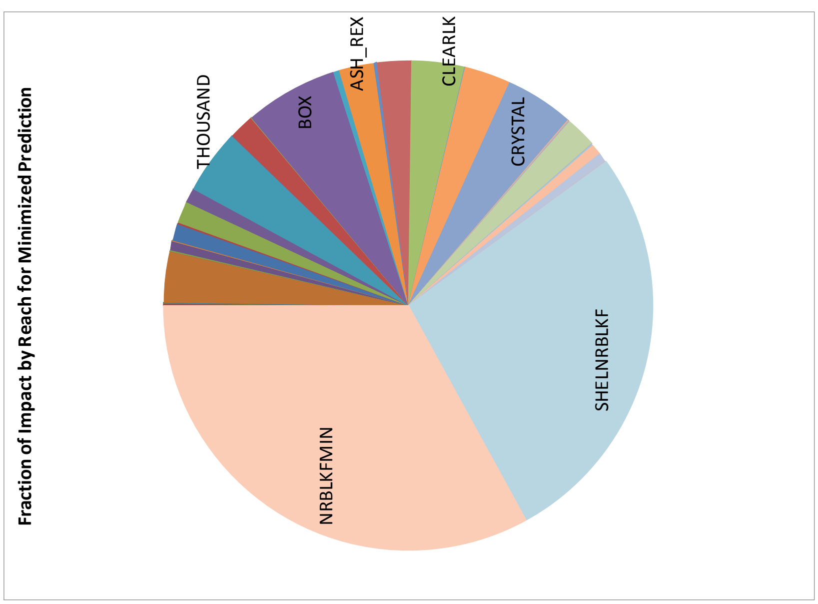
Appendix B; Filtered/Unfiltered Test Charts

Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

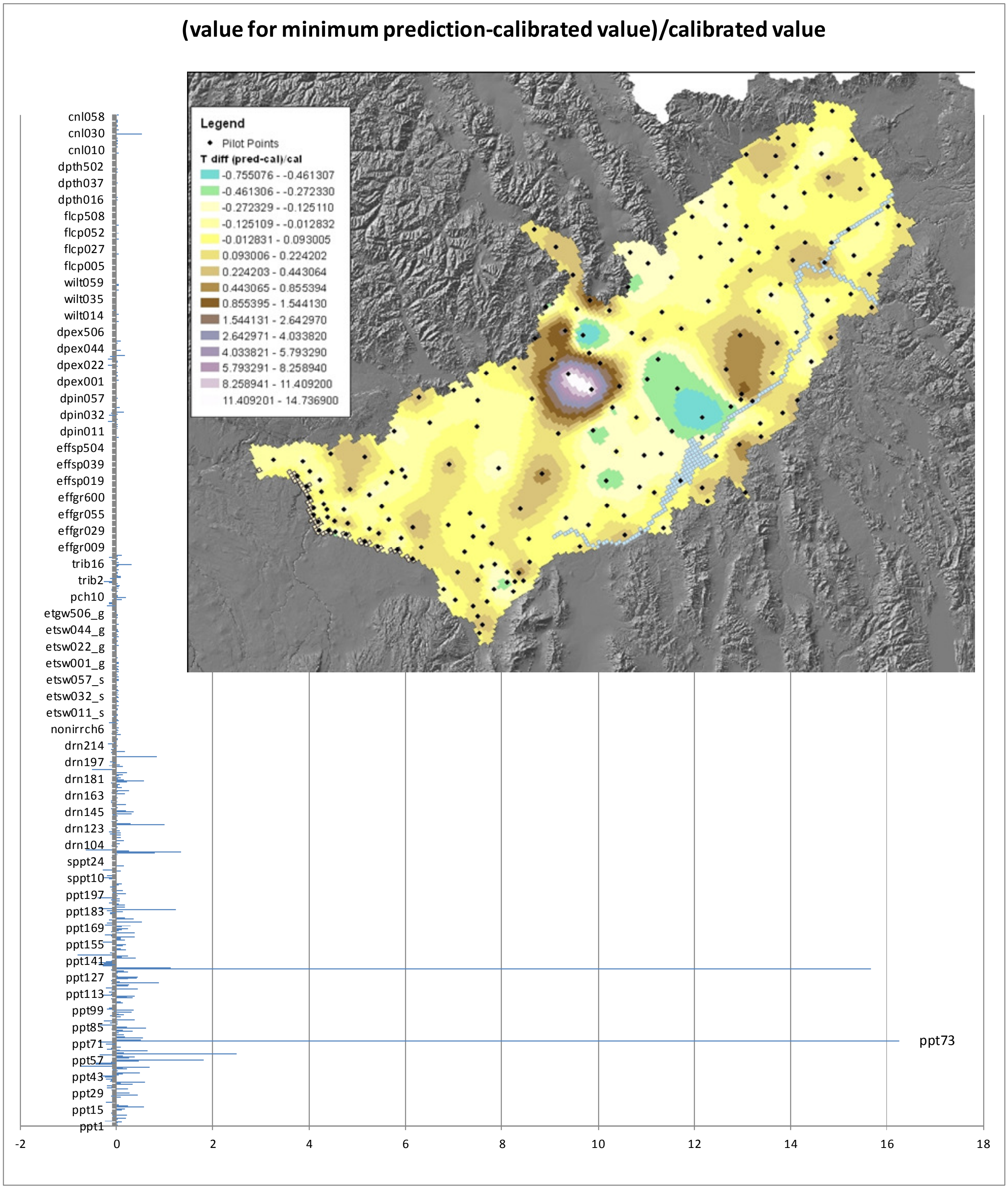


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

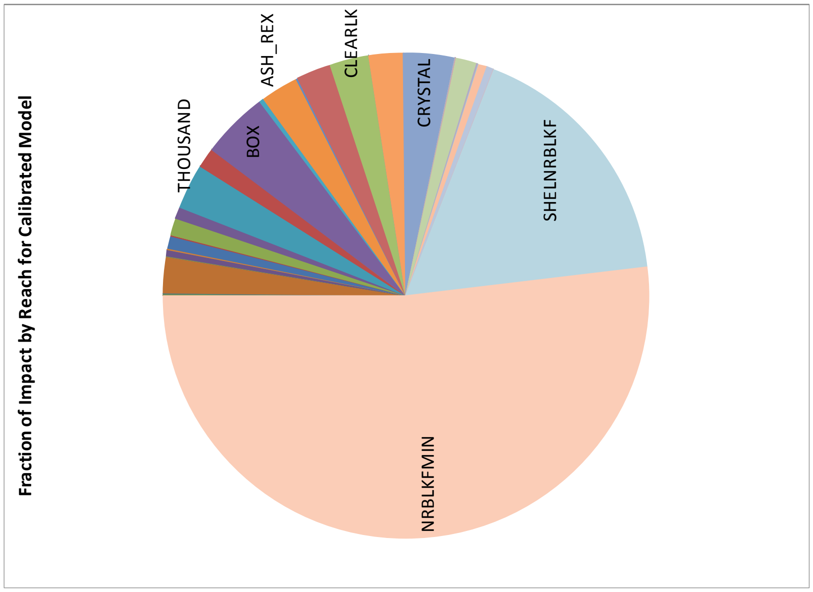


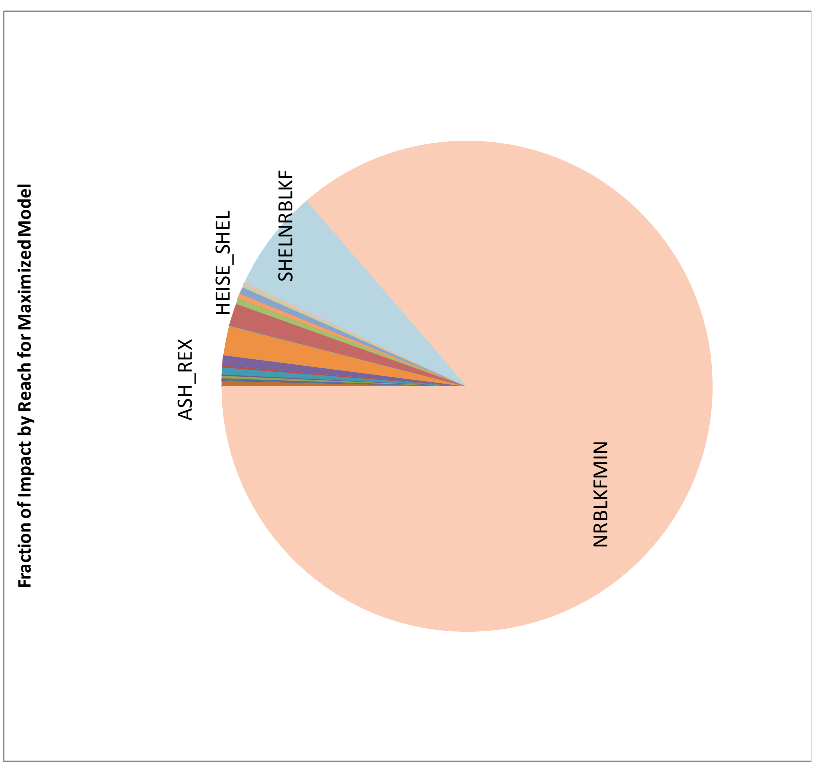


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

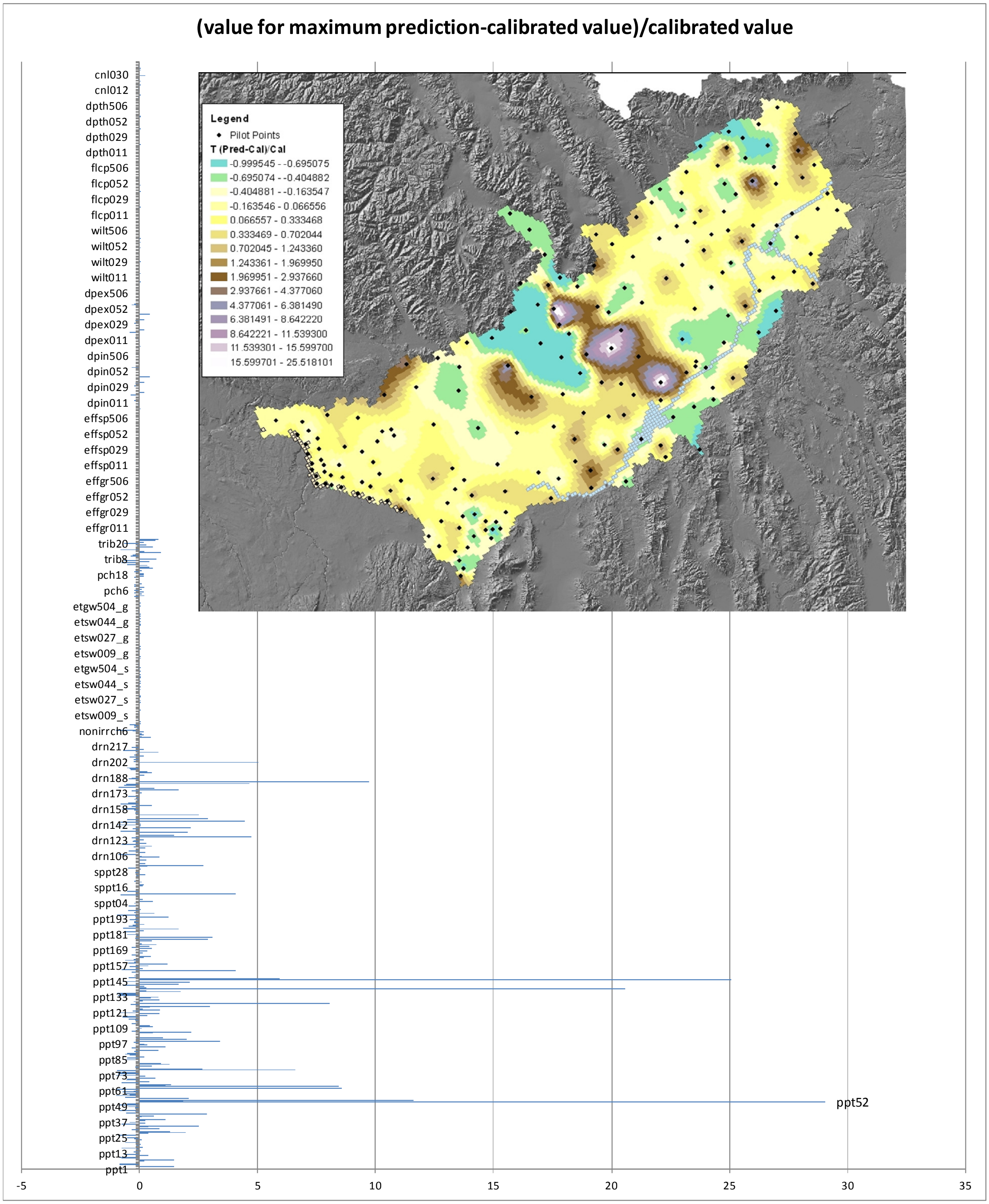


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

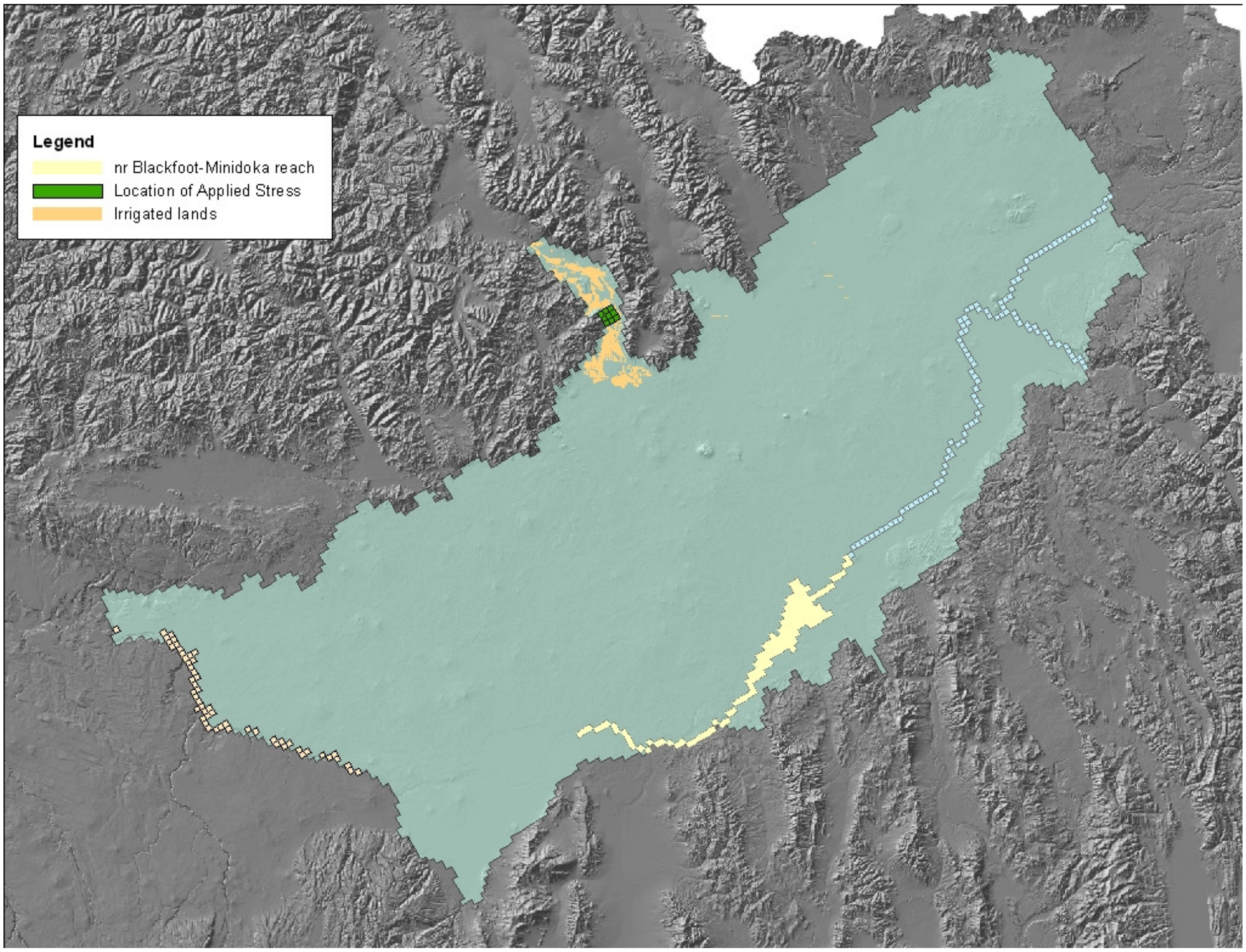




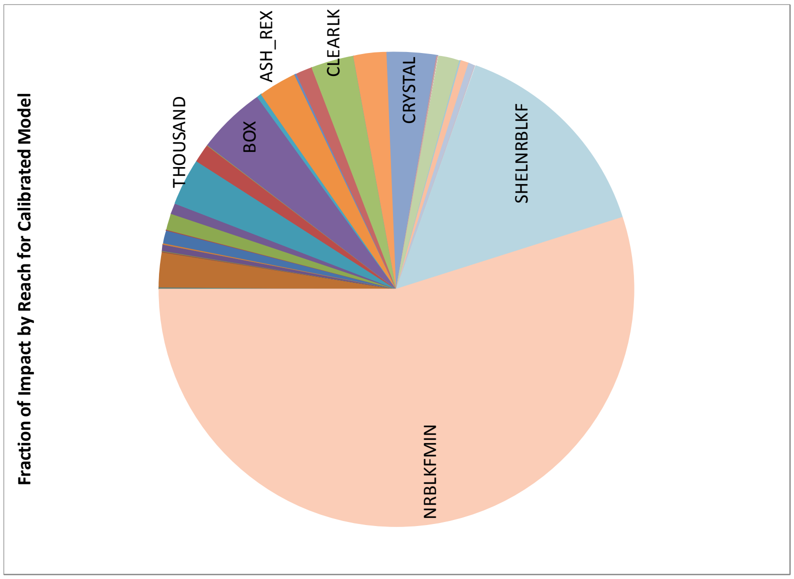
Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116A008.

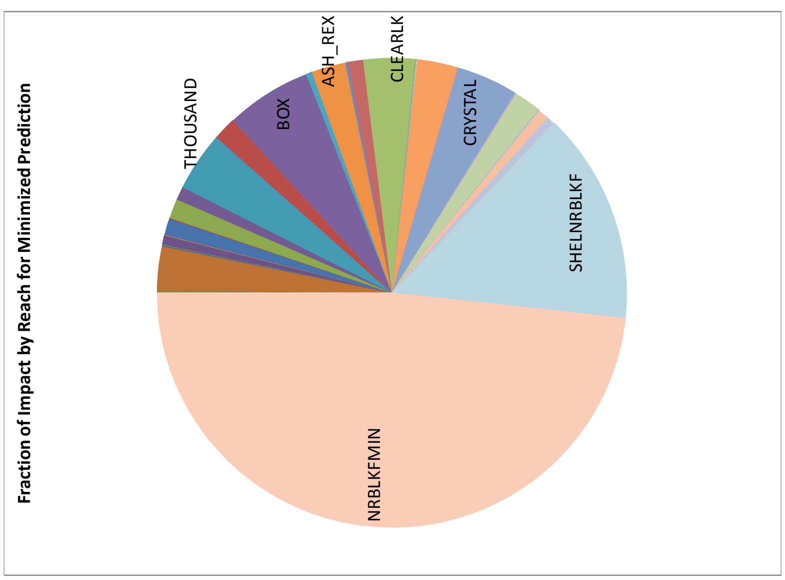


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116Afilt.

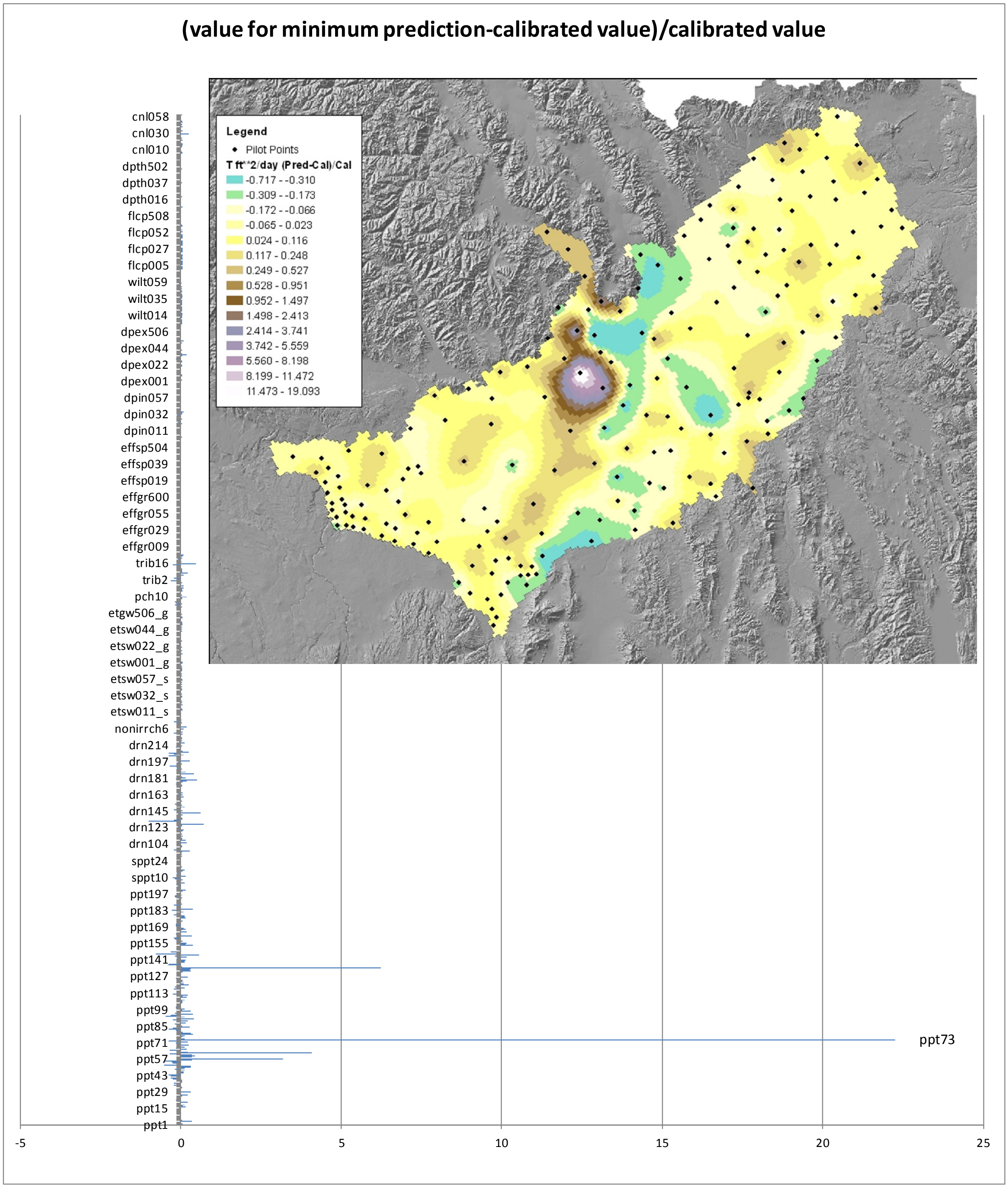


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116Afilt.

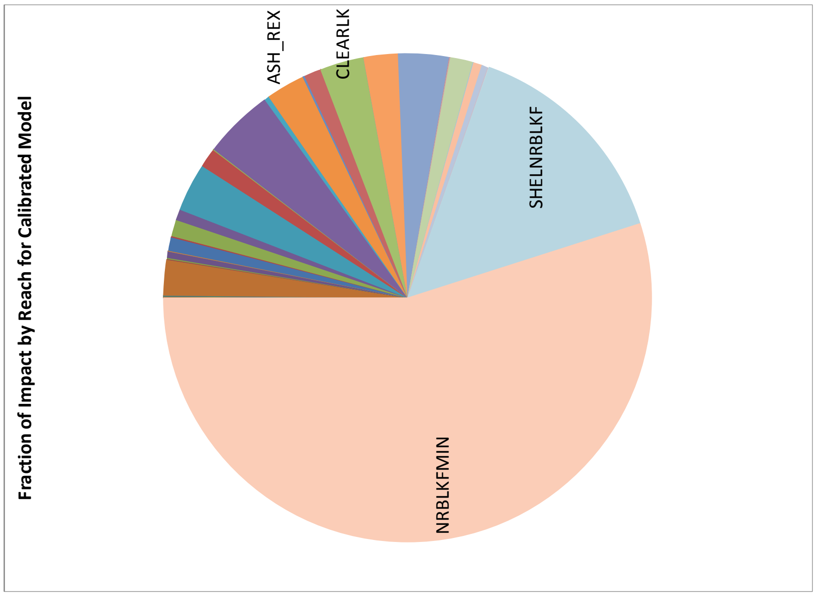


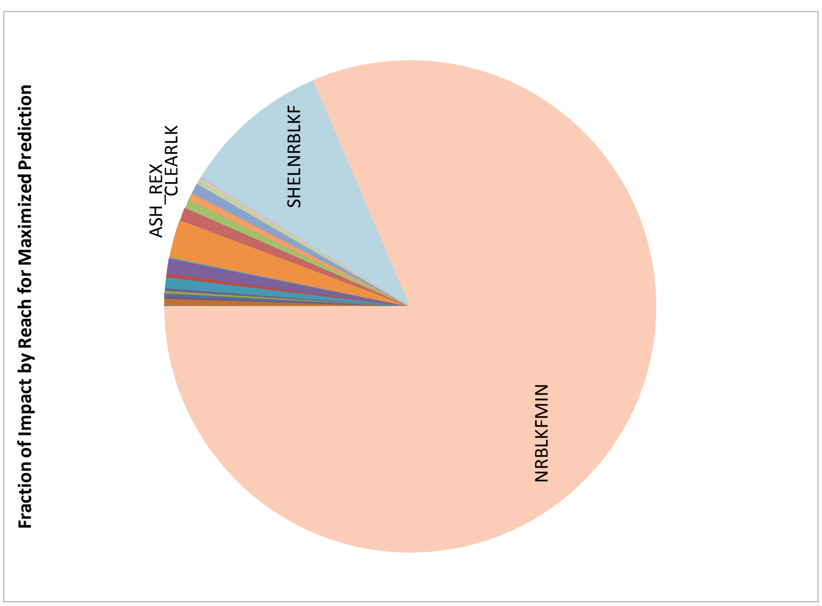


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116Afilt.

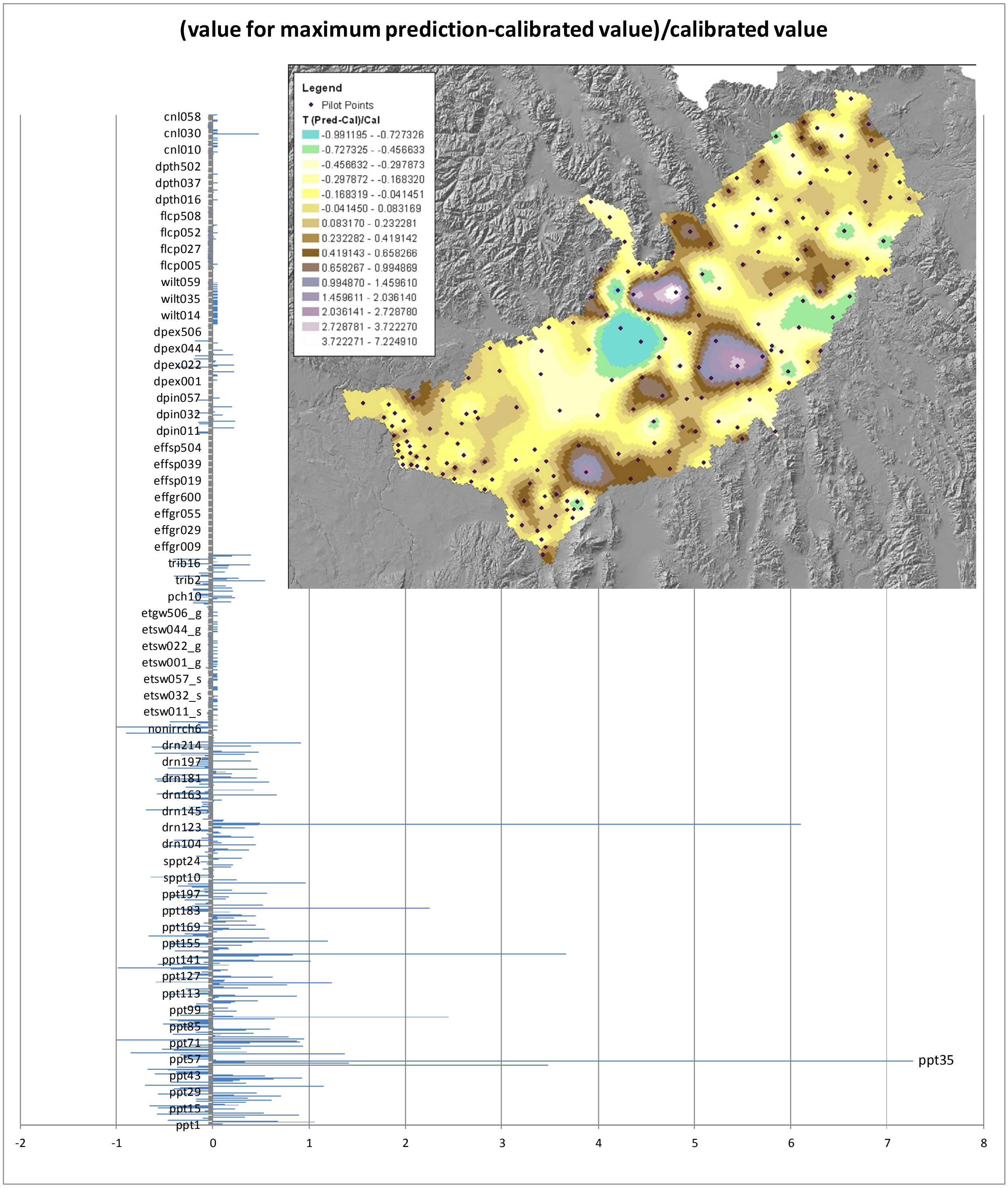


Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116Afilt.





Impact of Water District 34 on nr Blackfoot-Minidoka using calibration run E120116Afilt.



Appendix C; Parameter List and Descriptions

ppt1	Pilot point 1
ppt2	Pilot point 2
ppt3	Pilot point 3
ppt4	Pilot point 4
ppt5	Pilot point 5
ppt6	Pilot point 6
ppt7	Pilot point 7
ppt8	Pilot point 8
ppt9	Pilot point 9
ppt10	Pilot point 10
ppt11	Pilot point 11
ppt12	Pilot point 12
ppt13	Pilot point 13
ppt14	Pilot point 14
ppt15	Pilot point 15
ppt16	Pilot point 16
ppt17	Pilot point 17
ppt18	Pilot point 18
ppt19	Pilot point 19
ppt20	Pilot point 20
ppt21	Pilot point 21
ppt22	Pilot point 22
ppt23	Pilot point 23
ppt24	Pilot point 24
ppt25	Pilot point 15
ppt26	Pilot point 26
ppt27	Pilot point 27
ppt28	Pilot point 28
ppt29	Pilot point 29
ppt30	Pilot point 30
ppt31	Pilot point 31
ppt32	Pilot point 32
ppt33	Pilot point 33
ppt34	Pilot point 34
ppt35	Pilot point 35
ppt36	Pilot point 36
ppt37	Pilot point 37
ppt38	Pilot point 38
ppt39	Pilot point 39
ppt40	Pilot point 40
ppt41	Pilot point 41
ppt42	Pilot point 42

ppt43	Pilot point 43
ppt44	Pilot point 44
ppt45	Pilot point 45
ppt46	Pilot point 46
ppt47	Pilot point 47
ppt48	Pilot point 48
ppt49	Pilot point 49
ppt50	Pilot point 50
ppt51	Pilot point 51
ppt52	Pilot point 52
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ppt66	Pilot point 66
ppt67	Pilot point 67
ppt68	Pilot point 68
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ppt76	Pilot point 76
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ppt78	Pilot point 78
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ppt80	Pilot point 80
ppt81	Pilot point 81
ppt82	Pilot point 82
ppt83	Pilot point 83
ppt84	Pilot point 84

ppt85	Pilot point 85
ppt86	Pilot point 86
ppt87	Pilot point 87
ppt88	Pilot point 88
ppt89	Pilot point 89
ppt90	Pilot point 90
ppt91	Pilot point 91
ppt92	Pilot point 92
ppt93	Pilot point 93
ppt94	Pilot point 94
ppt95	Pilot point 95
ppt96	Pilot point 96
ppt97	Pilot point 97
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ppt100	Pilot point 100
ppt101	Pilot point 101
ppt102	Pilot point 102
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ppt104	Pilot point 104
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ppt120	Pilot point 120
ppt121	Pilot point 121
ppt122	Pilot point 122
ppt123	Pilot point 123
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ppt125	Pilot point 125
ppt126	Pilot point 126

ppt127	Pilot point 127
ppt128	Pilot point 128
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ppt130	Pilot point 130
ppt131	Pilot point 131
ppt132	Pilot point 132
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ppt135	Pilot point 135
ppt136	Pilot point 136
ppt137	Pilot point 137
ppt138	Pilot point 138
ppt139	Pilot point 139
ppt140	Pilot point 140
ppt141	Pilot point 141
ppt142	Pilot point 142
ppt143	Pilot point 143
ppt144	Pilot point 144
ppt145	Pilot point 145
ppt146	Pilot point 146
ppt147	Pilot point 147
ppt148	Pilot point 148
ppt149	Pilot point 149
ppt150	Pilot point 150
ppt151	Pilot point 151
ppt152	Pilot point 152
ppt153	Pilot point 153
ppt154	Pilot point 154
ppt155	Pilot point 155
ppt156	Pilot point 156
ppt157	Pilot point 157
ppt158	Pilot point 158
ppt159	Pilot point 159
ppt160	Pilot point 160
ppt161	Pilot point 161
ppt162	Pilot point 162
ppt163	Pilot point 163
ppt164	Pilot point 164
ppt165	Pilot point 165
ppt166	Pilot point 166
ppt167	Pilot point 167
ppt168	Pilot point 168

ppt169	Pilot point 169
ppt170	Pilot point 170
ppt171	Pilot point 171
ppt172	Pilot point 172
ppt173	Pilot point 173
ppt174	Pilot point 174
ppt175	Pilot point 175
ppt176	Pilot point 176
ppt177	Pilot point 177
ppt178	Pilot point 178
ppt179	Pilot point 179
ppt180	Pilot point 180
ppt181	Pilot point 181
ppt182	Pilot point 182
ppt183	Pilot point 183
ppt184	Pilot point 184
ppt185	Pilot point 185
ppt186	Pilot point 186
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ppt188	Pilot point 188
ppt189	Pilot point 189
ppt190	Pilot point 190
ppt191	Pilot point 191
ppt192	Pilot point 192
ppt193	Pilot point 193
ppt194	Pilot point 194
ppt195	Pilot point 195
ppt196	Pilot point 196
ppt197	Pilot point 197
ppt198	Pilot point 198
ppt199	Pilot point 199
ppt200	Pilot point 200
ppt201	Pilot point 201
sppt01	Specific yield point 1
sppt02	Specific yield point 2
sppt03	Specific yield point 3
sppt04	Specific yield point 4
sppt05	Specific yield point 5
sppt06	Specific yield point 6
sppt07	Specific yield point 7
sppt08	Specific yield point 8
sppt09	Specific yield point 9

sppt10 Specific yield point 10
sppt11 Specific yield point 11
sppt12 Specific yield point 12
sppt13 Specific yield point 13
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sppt15 Specific yield point 15
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sppt24 Specific yield point 24
sppt25 Specific yield point 25
sppt26 Specific yield point 26
sppt27 Specific yield point 27
sppt28 Specific yield point 28
a_r_cond Riverbed conductance for Ashton-Rexburg reach
h_s_cond Riverbed conductance for Heise-Shelley reach
s_b_cond Riverbed conductance for Shelley-near Blackfoot reach
b_n_cond Riverbed conductance for near Blackfoot-Neeley reach
amf_cond Riverbed conductance for bottom of American Falls Reservoir
n_m_cond Riverbed conductance for Neeley-Minidoka reach
drn101 Conductance for drain 101
drn102 Conductance for drain 102
drn103 Conductance for drain 103
drn104 Conductance for drain 104
drn105 Conductance for drain 105
drn106 Conductance for drain 106
drn108 Conductance for drain 108
drn109 Conductance for drain 109
drn110 Conductance for drain 110
drn112 Conductance for drain 112
drn113 Conductance for drain 113
drn114 Conductance for drain 114
drn116 Conductance for drain 116
drn117 Conductance for drain 117
drn119 Conductance for drain 119
drn120 Conductance for drain 120
drn122 Conductance for drain 122

drn123	Conductance for drain 123
drn125	Conductance for drain 125
drn126	Conductance for one of the drains in the Malad complex
drn128	Conductance for one of the drains in the Malad complex
drn129	Conductance for one of the drains in the Malad complex
drn130	Conductance for one of the drains in the Malad complex
drn133	Conductance for drain 133
drn135	Conductance for drain 135
drn136	Conductance for drain 136
drn137	Conductance for drain 137
drn139	Conductance for drain 139
drn140	Conductance for drain 140
drn142	Conductance for drain 142
drn143	Conductance for drain 143
drn145	Conductance for drain 145
drn146	Conductance for drain 146
drn147	Conductance for drain 147
drn148	Conductance for one of the drains in the Three Springs complex
drn150	Conductance for one of the drains in the Three Springs complex.
drn151	Conductance for drain 151
drn153	Conductance for drain 153
drn154	Conductance for the drain representing Rangen
drn155	Conductance for one of the drains representing National Fish Hatchery/Magic
drn157	Conductance for one of the drains representing National Fish Hatchery/Magic
drn158	Conductance for one of the drains representing Thousand Springs/Magic
drn160	Conductance for one of the drains representing Thousand Springs/Magic
drn161	Conductance for drain 161
drn162	Conductance for drain 162
drn163	Conductance for drain 163
drn164	Conductance for one of the drains representing Sand Springs
drn165	Conductance for one of the drains representing Sand Springs
drn166	Conductance for drain 166
drn167	Conductance for drain 167
drn170	Conductance for drain 170
drn171	Conductance for drain 171
drn172	Conductance for drain 172
drn173	Conductance for the drain representing Briggs
drn174	Conductance for one of the drains representing Clear Lakes
drn176	Conductance for one of the drains representing Clear Lakes
drn177	Conductance for one of the drains representing Clear Lakes
drn179	Conductance for one of the drains representing Clear Lakes
drn180	Conductance for drain 180

drn181 Conductance for drain 181
drn182 Conductance for drain 182
drn184 Conductance for drain 194
drn185 Conductance for one of the drains representing Niagara
drn186 Conductance for one of the drains representing Niagara
drn187 Conductance for drain 187
drn188 Conductance for drain 188
drn189 Conductance for drain 189
drn190 Conductance for drain 190
drn191 Conductance for drain 191
drn193 Conductance for drain 193
drn194 Conductance for drain 194
drn195 Conductance for drain 195
drn196 Conductance for drain 196
drn197 Conductance for drain 197
drn199 Conductance for drain 199
drn200 Conductance for drain 200
drn201 Conductance for drain 201
drn202 Conductance for the drain representing Blue Lake
drn203 Conductance for drain 203
drn205 Conductance for drain 205
drn206 Conductance for drain 206
drn208 Conductance for drain 208
drn209 Conductance for one of the drains representing Devils Corral
drn210 Conductance for one of the drains representing Devils Corral
drn211 Conductance for the drain representing Devils Washbowl
drn212 Conductance for drain 212
drn213 Conductance for drain 213
drn214 Conductance for drain 214
drn216 Conductance for drain 216
drn217 Conductance for drain 217
ghb001 General head boundary conductance for Lower Salmon Falls-King Hill reach
ghb002 General head boundary conductance for Buhl-Lower Salmon Falls reach
ghb003 General head boundary conductance for Thousand Springs/Magic/Ntl Fish Hatchery
ghb004 General head boundary conductance for Blue Heart
ghb005 General head boundary conductance for Kimberly-Buhl reach
ghb006 General head boundary conductance for Crystal Springs
nonirrch1 Scalar for non-irrigated recharge on thin soil in polygon 1
nonirrch2 Scalar for non-irrigated recharge on thin soil in polygon 2
nonirrch3 Scalar for non-irrigated recharge on thin soil in polygon 3
nonirrch4 Scalar for non-irrigated recharge on thin soil in polygon 4
nonirrch5 Scalar for non-irrigated recharge on thin soil in polygon 5

nonirrch6 Scalar for non-irrigated recharge on rock in polygon 6
nonirrch7 Scalar for non-irrigated recharge on rock in polygon 7
nonirrch8 Scalar for non-irrigated recharge on rock in polygon 8
nonirrch9 Scalar for non-irrigated recharge on thick soil in polygon 9
nonirrch10 Scalar for non-irrigated recharge thick soil in polygon 10
nonirrch11 Scalar for on-irrigated recharge thick soil in polygon 11
wetlands ET from wetlands scalar
etsw000_s ET scalar for sprinkler irrigated land in the null entity
etsw001_s ET scalar for sprinkler irrigated land in the A&B entity
etsw002_s ET scalar for sprinkler irrigated land in the Aberdeen-Springfield entity
etsw005_s ET scalar for sprinkler irrigated land in the Big Lost River entity
etsw008_s ET scalar for sprinkler irrigated land in the Blaine Co entity
etsw009_s ET scalar for sprinkler irrigated land in the Burgess entity
etsw010_s ET scalar for sprinkler irrigated land in the Burley entity
etsw011_s ET scalar for sprinkler irrigated land in the Butte/Market Lake entity
etsw012_s ET scalar for sprinkler irrigated land in the Canyon entity
etsw014_s ET scalar for sprinkler irrigated land in the Blackfoot entity
etsw015_s ET scalar for sprinkler irrigated land in the Dewey entity
etsw016_s ET scalar for sprinkler irrigated land in the Egin entity
etsw018_s ET scalar for sprinkler irrigated land in the Falls entity
etsw019_s ET scalar for sprinkler irrigated land in the Fort Hall entity
etsw020_s ET scalar for sprinkler irrigated land in the Harrison entity
etsw022_s ET scalar for sprinkler irrigated land in the Idaho entity
etsw025_s ET scalar for sprinkler irrigated land in the Little Wood entity
etsw027_s ET scalar for sprinkler irrigated land in the Milner entity
etsw028_s ET scalar for sprinkler irrigated land in the Minidoka entity
etsw029_s ET scalar for sprinkler irrigated land in the Mud Lake entity
etsw030_s ET scalar for sprinkler irrigated land in the New Sweden entity
etsw032_s ET scalar for sprinkler irrigated land in the Northside entity
etsw034_s ET scalar for sprinkler irrigated land in the Peoples entity
etsw035_s ET scalar for sprinkler irrigated land in the Progressive entity
etsw036_s ET scalar for sprinkler irrigated land in the Liberty entity
etsw037_s ET scalar for sprinkler irrigated land in the Reno entity
etsw038_s ET scalar for sprinkler irrigated land in the Rexburg entity
etsw039_s ET scalar for sprinkler irrigated land in the Chester entity
etsw040_s ET scalar for sprinkler irrigated land in the Oakley entity
etsw044_s ET scalar for sprinkler irrigated land in the Monteview entity
etsw051_s ET scalar for sprinkler irrigated land in the Dubois entity
etsw052_s ET scalar for sprinkler irrigated land in the Small entity
etsw053_s ET scalar for sprinkler irrigated land in the Howe entity
etsw055_s ET scalar for sprinkler irrigated land in the Labelle entity
etsw056_s ET scalar for sprinkler irrigated land in the Sugar City entity

etsw057_s ET scalar for sprinkler irrigated land in the Blackfoot-Chubbuck entity
etsw058_s ET scalar for sprinkler irrigated land in the American Falls 2 entity
etsw059_s ET scalar for sprinkler irrigated land in the Gooding-Richfield entity
etgw501_s ET scalar for sprinkler irrigated land in Ground Water entity 501
etgw502_s ET scalar for sprinkler irrigated land in Ground Water entity 502
etgw503_s ET scalar for sprinkler irrigated land in Ground Water entity 503
etgw504_s ET scalar for sprinkler irrigated land in Ground Water entity 504
etgw505_s ET scalar for sprinkler irrigated land in Ground Water entity 505
etgw506_s ET scalar for sprinkler irrigated land in Ground Water entity 506
etgw507_s ET scalar for sprinkler irrigated land in Ground Water entity 507
etgw508_s ET scalar for sprinkler irrigated land in Ground Water entity 508
etgw509_s ET scalar for sprinkler irrigated land in Ground Water entity 509
etgw600_s ET scalar for sprinkler irrigated land in Ground Water entity 600
etsw000_g ET scalar for gravity irrigated land in the null entity
etsw001_g ET scalar for gravity irrigated land in the A&B entity
etsw002_g ET scalar for gravity irrigated land in the Aberdeen-Springfield entity
etsw005_g ET scalar for gravity irrigated land in the Big Lost River entity
etsw008_g ET scalar for gravity irrigated land in the Blaine Co entity
etsw009_g ET scalar for gravity irrigated land in the Burgess entity
etsw010_g ET scalar for gravity irrigated land in the Burley entity
etsw011_g ET scalar for gravity irrigated land in the Butte/Market Lake entity
etsw012_g ET scalar for gravity irrigated land in the Canyon entity
etsw014_g ET scalar for gravity irrigated land in the Blackfoot entity
etsw015_g ET scalar for gravity irrigated land in the Dewey entity
etsw016_g ET scalar for gravity irrigated land in the Egin entity
etsw018_g ET scalar for gravity irrigated land in the Falls entity
etsw019_g ET scalar for gravity irrigated land in the Fort Hall entity
etsw020_g ET scalar for gravity irrigated land in the Harrison entity
etsw022_g ET scalar for gravity irrigated land in the Idaho entity
etsw025_g ET scalar for gravity irrigated land in the Little Wood entity
etsw027_g ET scalar for gravity irrigated land in the Milner entity
etsw028_g ET scalar for gravity irrigated land in the Minidoka entity
etsw029_g ET scalar for gravity irrigated land in the Mud Lake entity
etsw030_g ET scalar for gravity irrigated land in the New Sweden entity
etsw032_g ET scalar for gravity irrigated land in the Northside entity
etsw034_g ET scalar for gravity irrigated land in the Peoples entity
etsw035_g ET scalar for gravity irrigated land in the Progressive entity
etsw036_g ET scalar for gravity irrigated land in the Liberty entity
etsw037_g ET scalar for gravity irrigated land in the Reno entity
etsw038_g ET scalar for gravity irrigated land in the Rexburg entity
etsw039_g ET scalar for gravity irrigated land in the Chester entity
etsw040_g ET scalar for gravity irrigated land in the Oakley entity

etsw044_g ET scalar for gravity irrigated land in the Monteview entity
etsw051_g ET scalar for gravity irrigated land in the Dubois entity
etsw052_g ET scalar for gravity irrigated land in the Small entity
etsw053_g ET scalar for gravity irrigated land in the Howe entity
etsw055_g ET scalar for gravity irrigated land in the Labelle entity
etsw056_g ET scalar for gravity irrigated land in the Sugar City entity
etsw057_g ET scalar for gravity irrigated land in the Blackfoot-Chubbuck entity
etsw058_g ET scalar for gravity irrigated land in the American Falls 2 entity
etsw059_g ET scalar for gravity irrigated land in the Gooding-Richfield entity
etgw501_g ET scalar for gravity irrigated land in Ground Water entity 501
etgw502_g ET scalar for gravity irrigated land in Ground Water entity 502
etgw503_g ET scalar for gravity irrigated land in Ground Water entity 503
etgw504_g ET scalar for gravity irrigated land in Ground Water entity 504
etgw505_g ET scalar for gravity irrigated land in Ground Water entity 505
etgw506_g ET scalar for gravity irrigated land in Ground Water entity 506
etgw507_g ET scalar for gravity irrigated land in Ground Water entity 507
etgw508_g ET scalar for gravity irrigated land in Ground Water entity 508
etgw509_g ET scalar for gravity irrigated land in Ground Water entity 509
etgw600_g ET scalar for gravity irrigated land in Ground Water entity 600
pch1 Perched seepage scalar for Camas Cr
pch2 Perched seepage scalar for segment 2 of the Big Lost River
pch3 Perched seepage scalar for segment 3 of the Big Lost River
pch4 Perched seepage scalar for segment 4 of the Big Lost River
pch5 Perched seepage scalar for the Little Lost River
pch6 Perched seepage scalar for Medicine Lodge Cr
pch7 Perched seepage scalar for Malad River
pch8 Perched seepage scalar for Birch Cr
pch9 Perched seepage scalar for segment 1 of the Big Lost River
pch10 Perched seepage scalar for Lone Tree
pch11 Perched seepage scalar for Basin 31 flood control basin
pch13 Perched seepage scalar for Mud Lake
pch14 Perched seepage scalar for Camas National Wildlife Refuge
pch15 Perched seepage scalar for Birch Cr hydropower Plant
pch16 Perched seepage scalar for Big Lost flood control basins
pch17 Perched seepage scalar for part of Twin Falls Canal
pch18 Perched seepage scalar for Lake Murtaugh
pch19 Perched seepage scalar for segment 1 of Beaver Cr
pch20 Perched seepage scalar for segment 2 of Beaver Cr
pch21 Perched seepage scalar for segment 1 of Little Wood River
pch22 Perched seepage scalar for Big Wood and segment 2 of Little Wood River
trib1 Tributary underflow scalar for Little Lost River
trib2 Tributary underflow scalar for Medicine Lodge Cr

trib3 Tributary underflow scalar for Birch Cr
trib4 Tributary underflow scalar for Beaver Cr
trib5 Tributary underflow scalar for Blackfoot River
trib6 Tributary underflow scalar for Silver Cr
trib7 Tributary underflow scalar for Little Wood River
trib8 Tributary underflow scalar for Big Wood River
trib9 Tributary underflow scalar for Teton River
trib10 Tributary underflow scalar for Rexburg Bench
trib11 Tributary underflow scalar for South Fork (Palisade)
trib12 Tributary underflow scalar for Willow Cr
trib13 Tributary underflow scalar for Bannock Cr (Am Falls)
trib14 Tributary underflow scalar for Raft River
trib15 Tributary underflow scalar for Big Lost River
trib16 Tributary underflow scalar for Henrys Fork
trib17 Tributary underflow scalar for Thorn Cr
trib18 Tributary underflow scalar for Clover Cr
trib19 Tributary underflow scalar for Lincoln and Ross Cr
trib20 Tributary underflow scalar for Portneuf River
trib21 Tributary underflow scalar for Rock Cr
trib22 Tributary underflow scalar for Goose Cr
trib23 Tributary underflow scalar for Rattle Snake and Pine Cr
trib24 Tributary underflow scalar for Camas Cr@
effgr000_g Maximum efficiency for gravity irrigated land in the null entity
effgr001_g Maximum efficiency for gravity irrigated land in the A&B entity
effgr002_g Maximum efficiency for gravity irrigated land in the Aberdeen-Springfield entity
effgr005_g Maximum efficiency for gravity irrigated land in the Big Lost River entity
effgr008_g Maximum efficiency for gravity irrigated land in the Blaine Co entity
effgr009_g Maximum efficiency for gravity irrigated land in the Burgess entity
effgr010_g Maximum efficiency for gravity irrigated land in the Burley entity
effgr011_g Maximum efficiency for gravity irrigated land in the Butte/Market Lake entity
effgr012_g Maximum efficiency for gravity irrigated land in the Canyon entity
effgr014_g Maximum efficiency for gravity irrigated land in the Blackfoot entity
effgr015_g Maximum efficiency for gravity irrigated land in the Dewey entity
effgr016_g Maximum efficiency for gravity irrigated land in the Egin entity
effgr018_g Maximum efficiency for gravity irrigated land in the Falls entity
effgr019_g Maximum efficiency for gravity irrigated land in the Fort Hall entity
effgr020_g Maximum efficiency for gravity irrigated land in the Harrison entity
effgr022_g Maximum efficiency for gravity irrigated land in the Idaho entity
effgr025_g Maximum efficiency for gravity irrigated land in the Little Wood entity
effgr027_g Maximum efficiency for gravity irrigated land in the Milner entity
effgr028_g Maximum efficiency for gravity irrigated land in the Minidoka entity
effgr029_g Maximum efficiency for gravity irrigated land in the Mud Lake entity

effgr030_g Maximum efficiency for gravity irrigated land in the New Sweden entity
effgr032_g Maximum efficiency for gravity irrigated land in the Northside entity
effgr034_g Maximum efficiency for gravity irrigated land in the Peoples entity
effgr035_g Maximum efficiency for gravity irrigated land in the Progressive entity
effgr036_g Maximum efficiency for gravity irrigated land in the Liberty entity
effgr037_g Maximum efficiency for gravity irrigated land in the Reno entity
effgr038_g Maximum efficiency for gravity irrigated land in the Rexburg entity
effgr039_g Maximum efficiency for gravity irrigated land in the Chester entity
effgr040_g Maximum efficiency for gravity irrigated land in the Oakley entity
effgr044_g Maximum efficiency for gravity irrigated land in the Monteview entity
effgr051_g Maximum efficiency for gravity irrigated land in the Dubois entity
effgr052_g Maximum efficiency for gravity irrigated land in the Small entity
effgr053_g Maximum efficiency for gravity irrigated land in the Howe entity
effgr055_g Maximum efficiency for gravity irrigated land in the Labelle entity
effgr056_g Maximum efficiency for gravity irrigated land in the Sugar City entity
effgr057_g Maximum efficiency for gravity irrigated land in the Blackfoot-Chubbuck entity
effgr058_g Maximum efficiency for gravity irrigated land in the American Falls 2 entity
effgr059_g Maximum efficiency for gravity irrigated land in the Gooding-Richfield entity
effgr501_g Maximum efficiency for gravity irrigated land in Ground Water entity 501
effgr502_g Maximum efficiency for gravity irrigated land in Ground Water entity 502
effgr503_g Maximum efficiency for gravity irrigated land in Ground Water entity 503
effgr504_g Maximum efficiency for gravity irrigated land in Ground Water entity 504
effgr505_g Maximum efficiency for gravity irrigated land in Ground Water entity 505
effgr506_g Maximum efficiency for gravity irrigated land in Ground Water entity 506
effgr507_g Maximum efficiency for gravity irrigated land in Ground Water entity 507
effgr508_g Maximum efficiency for gravity irrigated land in Ground Water entity 508
effgr509_g Maximum efficiency for gravity irrigated land in Ground Water entity 509
effgr600_g Maximum efficiency for gravity irrigated land in Ground Water entity 600
effsp000_g Maximum efficiency for sprinkler irrigated land in the null entity
effsp001_g Maximum efficiency for sprinkler irrigated land in the A&B entity
effsp002_g Maximum efficiency for sprinkler irrigated land in the Aberdeen-Springfield entity
effsp005_g Maximum efficiency for sprinkler irrigated land in the Big Lost River entity
effsp008_g Maximum efficiency for sprinkler irrigated land in the Blaine Co entity
effsp009_g Maximum efficiency for sprinkler irrigated land in the Burgess entity
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dpex000 Deep percolation fraction for excess water for irrigated land in the null entity
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dpth600 Rooting depth for irrigated land in Ground Water entity 600
cnl001 Scalar for canal seepage in the A&B entity
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cnl058 Scalar for canal seepage in the American Falls 2 entity
cnl059 Scalar for canal seepage in the Gooding-Richfield entity

Appendix D; Color Ramp for Pie Diagrams

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D035014
D036014
MALAD
D037014
BIRCH
D038014
BIGSP
D040013
D040014
THREESP
TUCKER
RANGEN
NTLFSHH
THOUSAND
D045011
D045012
SAND
D047011
BOX
BANBURY
ASH_REX
BRIGGS
HEISE_SHEL
CLEARLK

D050014
D051014
NIAGARA
CRYSTAL
D057020
D058020
ELISON
D059021
D059022
D061023
D062023
BLUELK
D064026
D065027
DEVILC
DEVILW
D068029
D069029
D070030
SHELNRBLKF
NRBLKFMIN

Appendix E; ESHMC Review Comments and IDWR Responses

Comments from Chuck Brendecke

The procedure that was used is termed “predictive analysis” by Doherty and I think it’s important to maintain the fine points of the distinctions between predictive analysis, predictive uncertainty (which is a larger topic) and model uncertainty (which is larger still). Otherwise there is a risk that the reader will view the predictive analysis as the whole story.

IDWR response: Partial accept. We recognize that our analysis is not the whole story, and will enhance our discussion of its shortcomings, but pg 27 of Doherty and others (2010) includes a discussion of the maximization/minimization technique, so it seems to us that it is a legitimate predictive uncertainty analysis.

The last sentence of the abstract proposes the filtered/unfiltered analysis to “try and reduce” the uncertainty identified in the analysis. It seems to be that “evaluate the impact of data noise on” would be a better phrase. The former suggests that our goal is more to improve the optics than it is to get a complete understanding.

IDWR response: Accept.

Chuck

Charles M. Brendecke, PhD, PE

Principal

AMEC Environment & Infrastructure

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Boulder, CO 80302

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(303)442-0616 fax

Comments from Lyle Swank

Allan,

Here are a couple of comments from the WD100, WD110 and WD120 areas that were forwarded to me. My thoughts on the various steady state vs. steady flow and transient conditions are included also. Although we are late with the comments, I hope these comments are valuable and worthwhile.

1) Centroid Location:

There is a concern in the methodology of the uncertainty analysis of the first parameter of the report. "Identify the centroid of the irrigated lands within the water district."

Some centroids near a reach of the river may not be a good representation of the entire water district. Specifically WD120 and 100 have a Centroid that is in close proximity to the river reaches. This could skew the accuracy of the analysis.

My understanding of the Centroid is that it is defined by the irrigated lands within the water district. Perhaps it would be more accurate to create a centroid based on an equidistance of travel time to river from wells. This would pull the Centroid away from the river reach and place it in a better represented location of the average flow time in the water district.

> Scott Bergendorf
> Water Right Agent,
> WD100, WD110, WD120
>
> James Cefalo
> WD100, WD110, WD120
> Watermaster

IDWR Response: Partial accept. We will add a discussion stating that we are using water districts to position centroids so that we have a wide geographic distribution of stress locations, not so that we can assign uncertainty to a particular water district. We chose the centroid of the irrigated lands rather than the geographic center so that the stress would be applied in an irrigated area not in an un-irrigated area. Much of irrigated land is near the Snake River, so we would have been concerned if none of the centroids had been near the river.

2) Models are most accurate when they are representing either Steady-State/Steady Flow or a more transient condition. For a transient condition such as the timing of a runoff, the time period can be critically important. Because ESPAM V.2 is modeling a change in water table levels over years, it has elements of both steady state/steady flow and transient properties. Within the highly variable years, you have time periods when the groundwater is being replenished by surface water flows and time periods when surface water is being replenished by groundwater depending on the water table at the time of the year. Not all reaches of the Snake River will change with the same level of flood or drought. This changing gain/loss and how various reaches change based on the "communication" of the groundwater to surface water is still not well understood. Until these timing issues and groundwater levels are better understood, there are limits to how well the ESPAM V.2 can be used to model conditions ranging from flood to drought within long periods of records. There is an obvious uncertainty

band width to go along with these unknowns especially in the upper Snake River portion above the Snake River Neeley gage.

IDWR Response: Accept. There is uncertainty regarding the timing of when reaches of the river are gaining and losing. Unfortunately the reach gain and loss data that we use contain significant noise (see Figure 3). This analysis appears to identify the noisy reach gain and loss data as a weakness. I will add a discussion stating that even when filtered, the timing will remain a weakness until the source of the noise in the reach-gain data can be identified and removed.

Lyle Swank, P.E.

Watermaster WD01

900 N. Skyline

Idaho Falls, Id. 83402

Comments from Dave Colvin

Excellent summary of the dual calibration process. I believe you said it in a more concise, comprehensive, and understandable way than Doherty himself! Can I quote you in the future?

I am a little concerned that people will read the abstract, the summary, and nothing else. That's not necessarily a comment on the report itself, but rather a concern with the audience.

I was left wanting a little more explanation of the difference between predictive uncertainty analysis, and different types of error analysis. Is there a way to summarize or at least reference the issues presented in http://www.idwr.idaho.gov/Browse/WaterInfo/ESPAM/ESHMC%20Updated%20White%20Paper/ ? The main issues I'd like to see brought up are the sources of uncertainty, the spatial/temporal variability of these uncertainty sources, and which of these uncertainty sources are evaluated by the constrained minimization/maximization method. I think that characterizing the dual calibration approach as predictive uncertainty analysis is a bit of a stretch, but I understand your dilemma in how to explain this to such a wide audience.

IDWR Response: Accept.

You allude to the benefit that uncertainty analysis gives to identifying the adjustable parameters that need additional information collected for. I personally think that this is the greatest benefit of uncertainty analysis, but of course everyone always focuses on the "predictive" uncertainty results. If you agree, could you make an abstract and/or summary statement somewhere that the original calibration result is the most probable given the available data, and that the predictive uncertainty result ranges necessarily rely on models that have a poorer calibration?

I also have some minor comments:

1. Page 3, second paragraph: "...*18% (3/17) of the uncertainty analyses identified predictions with uncertainty greater than 0.10. Interestingly all the predictions with high uncertainty evaluated...*" If someone reads this independent of the rest of the report, I'm not sure they'll understand what 0.10 means. Maybe include something similar to page 8, paragraph 4 explanation?

IDWR Response: Accept.

2. Page 10, paragraphs 2, 3, and 4: The descriptions of why these results had small ranges seems to imply that the uncertainty analysis was deficient in some, way, which maybe it was. But couldn't it also be explained that the available observation data constrain the calibration results so that ESPAM 2.0 is actually an excellent predictor at these locations?

IDWR Response: Accept. We are puzzled, the descriptions were supposed to imply that the data constrained the calibration, we will firm up that discussion.

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Comments from Bryce Contor

From: bcontor.rm@gmail.com on behalf of Bryce Contor [bcontor@rockymountainenvironmental.com]
Sent: Thursday, November 01, 2012 8:25 PM
To: Wylie, Allan
Cc: Blew, David; Chuck Brockway; chuck.brendecke; Dave Colvin; David Hoekema; David Kampwerth; Greg Sullivan; Gregg S. Ten Eyck; Hal Anderson; J. D. May; Jack Harrison; Janak Timilsena; Jeff Sondrup; Jennifer Johnson; Jim Bartolino; Jim Brannon; John Koreny; John Lindgren; Johnson, Gary; Jon Bowling; Ken Skinner; Linda Lemmon
Subject: Uncertainty report

Allan -
I realize the report is final and that I am deliquent in my single comment:

On page 9 the report states

"It is only after the impact differences (range) becomes large, say 0.10 or greater, that the uncertainty becomes a practical issue."

The practical effect of a difference in modeled results depends entirely upon the administrative question to which the model is applied. My understanding from both Jeff Peppersack and Shelley Keen is that there is no deminimus consideration for mitigation requirements for new water rights. Our experience has been that sometimes large mitigation events are required to satisfy very small modeled requirements. Even with groundwater transfers, when the modeled effects are just barely over the deminimus threshhold, it often requires mitigation of many tens of acre feet per trimester to satisfy single-digit modeled impacts. While doubling a single-digit effect seems trivial, the resultant doubling of a large mitigation effort may not be trivial.

IDWR Response: Accept. We will adjust the paragraph to point out that, from a model development perspective, uncertainty will always exist. The model weaknesses we are looking for with the analyses are large.

I apologize for not getting this to you sooner.

Bryce

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